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CHAIRMAN: Yoshio HIRAMATSU

SOCIETIES ORGANIZING THE COMMITTEE

JAPAN SOCIETY OF CIVIL ENGINEERS
Yotsuya 1-chome, Shinjuku-ku, Tokyo

THE JAPANESE SOCIETY OF SOIL MECHANICS AND FOUNDATION ENGINEERING
Sugayama-Building, Kanda Awaji-cho 2-23, Chiyoda-ku, Tokyo

THE MINING AND METALLURGICAL INSTITUTE OF JAPAN
5-4, Ginza 8-chome, Chuo-ku, Tokyo

THE SOCIETY OF MATERIALS SCIENCE, JAPAN
1 Yoshida Izumidono-cho, Sakyo-ku, Kyoto

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PREFACE

The "Rock Mechanics in Japan, Volume IV, 1983", published by the Japanese Committee for ISRM introduces the research activities on rock mechanics in Japan from 1979 to 1981.

The Japanese Committee for ISRM is organized under the cooperation of four societies; Japan Society of Civil Engineers, The Japanese Society of Soil Mechanics and Foundation Engineering, The Mining and Metallurgical Institute of Japan and The Society of Materials Science, Japan. This Committee held the International Symposium on Weak Rock – Soft, Fractured and Weathered Rock, in September 1981 in Tokyo with great success.

The Rock Mechanics in Japan, Volume IV, 1983 consists of three parts. In the first part is described the brief comments on the activities of the Japanese Committee for ISRM and on the research activities of the related four societies, the second part the abstracts of all the papers on rock mechanics appeared in the journals and proceedings of these societies. The third part is the list of literatures of the papers on rock mechanics appeared in the twenty six publications issued by the four societies as well as the related societies and institutes in Japan. For convenience of citation, every paper is classified according to the International Geotechnical Classification System (I.G.C.).

A number of papers on rock mechanics have been published every year in Japan, but as they are mostly written in Japanese, it will be hard for foreigners to understand them. It will be a great pleasure if this publication be of use to introduce Japanese research activities to all the researchers and engineers in the world.

January 1983

Yoshio HIRAMATSU
Chairman of Japanese Committee
for ISRM

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I. RECENT ACTIVITIES

ON

ROCK MECHANICS IN JAPAN

1979—1981

RECENT ACTIVITIES ON ROCK MECHANICS

AT

JAPANESE COMMITTEE FOR ISRM

1. Brief History of Japanese Committee for ISRM

Since the second half of the 1950's, rock mechanics has been studied independently in Japan, in various fields such as mining, civil engineering, and construction including tunneling, dam foundation, bridge foundation, etc. During the 1960's, rock mechanics aroused sudden interest, and in 1964, the International Society of Rock Mechanics (ISRM) was established. Stimulated by the establishment of this society, the Japan Joint Committee for Rock Mechanics was established in 1964 by the Society of Civil Engineers, the Mining and Metallurgical Institute of Japan, the Japanese Society of Soil Mechanics and Foundation Engineering and the Society of Materials Science, Japan as the organization corresponding to ISRM in Japan, in order to realize the international exchange of the investigation results in each field and to promote the study of rock mechanics. For 15 years from 1964 to 1979, the above mentioned 4 societies have held joint symposiums every 3 years to promote the exchange of the investigation results in Japan and to make the international acitivity corresponding to the activity of ISRM, and to publish "Rock Mechanics in Japan" to introduce the investigation activities on rock mechanics in Japan at ISRM's congress.

Joint Committee for Rock Mechanics consisted of the group of investigators supported by these 4 societies, but it lacked economical foundation, so it had the following defects:

i) Since the works required for the activities of this committee have been processed by one of these 4 societies in turn every 3 years, those concerned have experienced inconvenience where the address and

staff of the Society's secretariat for international contact changed every 3 years.

ii) Various activities of this committee have been restricted by its weak economical foundation.

iii) This committee could not correspond to the activities of various ISRM committees which have been recently promoted vigorously because of its week economical foundation.

To correct these defects, it becomes necessary for the Joint Committee for Rock Mechanics to establish a permanent secretariat at a fixed address and to strengthen its economical foundation.

2. Present situation of Japanese Committee for ISRM

Those concerned eagerly hoped to hold an international rock mechanics symposium in Japan in 1981, so they endeavoured to organize a powerful investigation liaison organization regarding rock mechanics, taking this opportunity.

In August, 1979, Japanese Committee for ISRM consisting of 62 companies (the electric power companies, construction companies, geological survey companies, consultant companies, etc.) as patron members and 180 individual members under the support of the above mentioned 4 societies similar to the ISRM organizational structure was organized in order to realize the exchange of investigation results and to promote the study of rock mechanics in various fields in Japan, to establish the secretariat at the Japan Society of Civil Engineers permanently, and to commence full secretariat activities instead of activities of the Joint Committee for Rock Mechanics.

Since then, the preparations for the international rock mechanics symposium in 1981 have been promoted principally by Japanese Committee for ISRM

In the initial stage, the study of rock mechanics was promoted with an emphasis on jointed hard rock in Japan. However, dams of considerable scale and civil engineering construction projects on a large scale such as Honshu-Shikoku Connecting Bridge and Seikan Undersea Tunnel, etc. have

recently been constructed on soft/weak rocks. Those concerned have shown a deep interest in soft/weak rock and under the circumstances, the international symposium regarding soft, fractured and weathered rock was held from September 21 to September 24, 1981 in Tokyo.

During this symposium the following 5 subjects were eagerly examined.

1. Engineering property of weak rock.
2. On site investigation of weak rock.
3. Specialized theory and analysis of weak rock.
4. Adequate design and construction practice for weak rock.
5. Dynamics and tectonics of weak rock.

At this international symposium, 247 papers were submitted with the participation of 583 investigators (the foreign participants: 125 and the domestic participants: 458).

In addition, simultaneous with the holding of this international symposium, the meetings of various ISRM committees were held to promote the international exchange of investigation results concerning rock mechanics further.

Based on the results of this international symposium, the systematization of the correspondence to various ISRM committees etc. has been promoted principally by Japanese Committee for ISRM to realize closer international exchange of investigation results regarding rock mechanics and to promote the study of rock mechanics.

Dr. R. Iida, Vice-Chairman
Japanese Committee for ISRM

RECENT ACTIVITIES ON ROCK MECHANICS

AT

THE JAPAN SOCIETY OF CIVIL ENGINEERS

1. Organization of Rock Mechanics Committee

Rock Mechanics Committee consisting of 49 commissioners is or have been established at the Japan Society of Civil Engineers. The commissioners of this committee include the representatives of the investigators from various fields engaged in rock mechanics/engineering and work, such as enterprisers, contractors, consultants, scholoars of universities, etc. This committee has 4 divisions under its control. The first and the second divisions are organized according to the work field, namely, the first division is engaged in the study of dam construction, and the second division is engaged in the study of the tunnel. On the other hand, the third and the fourth divisions are organized according to the investigation fields, namely, the third division is engaged in the study of theory and testing, and the fourth division is engaged in the study of soft/weak rocks. Each division consists of the commissioners of slightly less than 35. The total of the commissioners of these 4 divisions is 135. This committee establishes its operational policy as the civil society regarding rock mechanics and is responsible for the adjustment among these divisions and for the cooperation, liaison, etc. to other societies.

2. Activities of divisions

The first division has investigated "the Treatment of Foundation of Fill Dam Abutment Rock Mass" principally during these 3 years. From the standpoint of the materials which constract dams, this investigation subject is roughtly classified into concrete dam and fill dam. Recently, the number of the fill type dams has increased owing to the geology of base

rock, economy, etc. The first division collected and analyzed data regarding the case history constructions of existing fill dams.

The second division is engaged in the study of tunnels. This division complied "Rock Classification for Tunneling" in November, 1979 (published in the journal of the Japan Society of Civil Engineers). Recently, it has studied "Geological Investigation and Rock Measurement for Tunneling". The investigation results of this study will be published in a separate volume in 1983. The purpose of this book is to supply the orderer and the order acceptor with the common field or ground to discuss technical problems on rock mechanics.

The third division has been engaged in the establishment of the guidelines regarding the in-situ deformation test and the shear test of rock mass and the preparation of the explanation of such guideline principally during the last 10 years. The results of this activity will be published in a separate volume during about June, 1983. This division is planning to prepare the evaluation standards of bore-hole loading test and to establish the measuring method of in-situ stress. The fourth division is engaged in the study of soft/weak rocks. This division has been engaged in the establishment of the investigation and test method of soft/weak rocks and the collection and arrangement of the examples of the investigation and construction on soft/weak rocks principally. The results of its activities, were published in "The Guideline of the Investigation and Test of Soft/Weak Rocks" (in 'Rock Mechancis '79' published by the Japanese ISRM Committee) in January, 1980. It also reported on the present situation and the tasks of the construction on soft/weak rocks in Japan at the 1981 ISRM Tokyo Symposium. It will publish an "Investigation, Design and Construction on Soft/Weak Rocks" in a separate volume during October, 1983.

Each division holds a meeting to report on the investigation results and the field observation tour, etc. simultaneous with the holding of the committee meeting.

3. Symposium and meeting on rock mechanics

(1) The 12th symposium on rock mechanics was held in February, 1979 with 23 reports and 230 participants.

(2) The Rock Mechanics Study Report Meeting was held in February, 1979 with 69 participants.

(3) The Rock Mechanics Study Report Meeting was held in November, 1979 with 61 participants.

(4) The 13th Symposium on Rock Mechanics was held in April, 1980 with 26 reports and 307 participants.

(5) The Rock Mechanics Study Report Meeting was held in March 1981 with 86 participants.

(6) The Rock Mechanics Study Report Meeting was held in October, 1981 with 69 participants.

Mr. T. Matsumoto, Chief Secretary
Rock Mechanics Committee of JSCE

RECENT ACTIVITIES ON ROCK MECHANICS AT THE JAPANESE SOCIETY OF SOIL MECHANICS AND FOUNDATION ENGINEERING

1. Purpose and activities in the past

The Rock Mechanics Committee of the Japanese Society of Soil Mechanics and Foundation Engineering was established in 1966 to investigate the mechanics of rock and soil exclusively. In the initial stage, its activities were promoted with the following intentions:

1) The investigation of the common and different mechanics properties between rock mass and soil to improve the knowledge of engineers in both fields mutually.
2) Handling of rock materials and soil materials synthetically as the structural foundation.

As the results of the activities of this committee, the "Terminology of Rock Engineering" in 1972 and "Engineering Properties of Rock and Their Applications to Design and Construction" in 1974 were published. This committee also held meetings 2-4 times annually to examine the actual examples of the and the test of rock mass in the field in Japan and to report on the new information of rock mechanics both home and abroad to exchange knowledge and information. It is also in charge of a part of the ISRM desk work as a member of the Japan National Group.

2. Recent activities

In 1979, the Rock Mechanics Committee of JSSMFE examined the applicability of the testing methods of soils such as bore-hole loading test, etc., for estimation of the in-situ mechanical properties of rock mass. This committee also investigated the actual conditions of the bore-hole

loading testing apparatus especially for rock mass of various kinds of these machines now in practical use and examined the results of a comparison of the bore-hole loading testing apparatus which is now being conducted by the Japan Highway Public Corporation. In addition, it discussed the revision policy of "Terminology of Rock Engineering" published by this committee and started the addition of the technical terms of engineering geology, geological engineering, tunneling, numerical analysis, etc. relating to the recent rock engineering and the deletion of some of the conventional technical terms which are seldom used and the review of the foreign languages, especially, French and German.

In 1980, this committee discussed the test, measurement, analysis, etc. of soft/weak rocks. It examined the discussion policy of these items in the future including the review of the Q system established by N. Barton, RMR method proposed by A. T. Bieniawski, the method of the Central Research Institute of Electric Power Industry, etc. and the discussion of the mechanical properties, the field testing and investigation method relating to mudstone, to investigate the possibility of rock mass for obtaining in-situ properties of soft/weak rock. The committee also reviewed the "Terminology of Rock Engineering" as with the preceding year and revised it.

The dam construction site in the mudstone zone was selected as the place of inspection visite. The committee visited the Donto Dam (the foundation rock of which consists of rhyolite and tuff breccia of the latter stage of Cretaceous period and fractured zone of 30-40 cm in depth on the river bed) constructed by the Ministry of Agriculture and Forestry. This committee also visited the Aina Tunnel field (the foundation rock of which consists of tuff breccia and mudstone) constructed by the Hanshin Highway Public Corporation at the same time. It discussed various problems relating to rock mechanics in these sites. As a result, it was confirmed that the investigation of mudstone by this committee in the future was meaningful. The committee was determined to discuss the properties of mudstone as materials, the properties of mudstone as base rock, the

instability by clay minerals and solidification degree of mudstone, and progressive failure, etc. of mudstone.

In 1981, the committee discussed the mechanical properties of mudstone, the ground properties of tunnel face and NATM bolt effect through lectures and the explanation of the data. In addition, the committee discussed the effect of rock bolt in jointed rock mass and the proposed topics of the present situation and problems of the tunnel field measurement engineering method.

Prof. T. Kawamoto, Former Chairman
Rock Mechanics Committee of JSSMFE

RECENT ACTIVITIES ON ROCK MECHANICS AT THE MINING AND METALLURGICAL INSTITUTE OF JAPAN

1. Rock mechanics at MMIJ

Rock mechanics has close relation with the mining of underground resources, the development of geothermal resources, the use of underground rock mass to store energy resources, environment preservation after mining resources, etc. This fact is the motive power to promote the study activities of rock mechanics at the Mining and Metallurgical Institute of Japan.

2. Recent activities

Table 1, shows the committees regarding rock mechanics organized during this period and their activities. Table 2 shows the papers, reports published in the journal of the Mining and Metallurgical Institute of Japan and the papers published at the spring and autumn meeting of this institute held in spring and autumn each year.

As these tables clearly show, the study activities of this institute covers the investigation subjects in the wide range, and shows new development in each investigation subject.

In the sutdy of the prpperties of rock, the rock test was conducted by means of a servo controlled testing machine by using not only the rate of axial strain but also the rate of volumetric strain and the rate of AE occurrence as the control signal to clarify the relationship between the macro deformation and failure and the micro cracking of rock. In the rock mass investigation and measurement field, hydraulic fracturing is going to be applied not only to the stress measurement but also to the geothermal development, and the new development is observed by the combination of

hydraulic fracturing with AE measurement for the orientation of failed face. The AE measurement will be a promising means to predict gas burst and rock burst in galley excavation presenting the possibility of such accidents by observing rock mass displacement, the gas pressure and flow rate, etc. simultaneously.

Table 1. Rock mechanics study committees

Study committee	Activity year			Publication	Publication year
	54	56	56		
Study of application of physical prospecting technique to rock physics	o			"Application of physical prospecting technique to investigation of properties of soil and rock"	1979
Preparation and use study of rock test data sheet	o	o	o		1971
Investigation and study of halt plan at large scale mine	o	o	o	"Investigation and study of open-pit technology in foreign countries"	1971
Technical study of rock bolt support in weak rocks	o	o	o	"Rock bolt support"	1981
Application of soil engineering technology in mines		o	o	"Application of soil mecahnics and rock mechanics in metal and coal mines	1981
Smooth blasting		o	o		
Hydraulic fracturing for geothermal development			o	"Hydraulic fracturing technology for geothermal development"	1981
Underground use technology in mines			o		

Table 2. Papers and Reports Published Regarding Rock Mechanics

Study subject	No. of papers and reports									Total
	1979			1980			1981			
	Journals	Spring meeting	Autumn meeting	Journals	Spring meeting	Autumn* meeting	Journals	Spring meeting	Autumn meeting	
Rock properties and rock testing method	1	20	6	11	23	0	5	20	2	88
Rock mass properties and rock mass testing method	4	9	5	9	12	0	4	10	1	54
Stress phenomenon and its control in metal mines	4	3	2	4	1	2	4	3	4	27
Stress phenomenon and its control in coal mines	7	7	2	6	6	6	8	6	7	55
Galley excavation and galley support	4	6	3	6	6	0	9	8	7	49
Ground surface subsidence	3	3	1	1	1	0	1	1	1	12
Open-pit mining and slope stability	3	2	6	0	2	1	2	5	0	21
Underground dam and water retention wall	0	0	5	2	1	0	1	0	0	9
Rock mass excavation and fracturing	9	10	8	6	4	0	5	4	12	58
Total number of papers and reports	35	60	38	45	56	9	39	57	34	373

* The autumn meeting was held as the third Japan-US meeting of the Mining and metallurgical Institute of Japan with papers in English having been submitted.

The investigation of the cause of the rock burst of a coal bed occurred in Kyushu Miike Coal Mine and an attempt to control the rock burst were the noteworthy results of the study of rock mechanics during this period.

It is desirable to develop rock mechanics and its applied technology as the basic learning in the field of the development of the underground resources showing the tendency of further deepening and larger scale based on the results of the study during this period.

Prof. S. Kinoshita, Chairman
Rock Mechanics Committee of MMIJ

RECENT ACTIVITIES IN ROCK MECHANICS

AT

THE SOCIETY OF MATERIALS SCIENCE, JAPAN

1. Committee on Rock Mechanics at SMS, J.

Committee on Rock Mechanics at SMS, J. performs the activities regarding rock mechanics principally. This committee was established in 1963 and had held 83 meetings by the end of 1981. As a related committee, a division regarding fracturing was established in 1971 and this division has performed its activities until now.

This committee consists of about 60 commissioners belonging to the geology, mineralogy, geophysics, seismology, civil engineering, resources engineering, etc. Therefore, this committee handles many fields, so it is used as the organization to examine rock mechanics from various angles and to study the boundary problems between different category of sciences and to exchange information. This is the outstanding feature of the Society of Materials Science, Japan.

The activities of this society include the holding of about 4 meetings every year, the compilation of the special number of rock mechanics of "Materials", the journal of this society, and the holding of lecture meetings, institutes and the organization of study visits. In addition, as a member of Japanese ISRM Committee, this committee participates in its various activities such as the holding of symposiums, etc. At the usual meeting of this committee, its activities are discussed and various topics are introduced and discussed actively.

2. Recent activities

The topics regarding geophysics taken up during these 3 years (1979-1981) are as follows:

Testing method for low rate of strain in rock and creep mechanism (proposed by H. Ito)

Damping of Love wave in soft ground and estimation of Q_s structure (proposed by Kishimoto)

Estimation of phase velocity of micro-vibration and transmission function (proposed by Horiie)

The topics regarding engineering, especially materials properties are as follows:

Multi-stage triaxial compression testing and hydraulic fracturing experiment by means of the stiff testing machine (proposed by Ohnishi and Ri)

Research on stiff testing machine of fire-brick materials (proposed by Nishihara and Miyamoto)

Recent topics of soft rock (proposed by Adachi)

AE occurrence mechanism and wave motion analysis of concrete materials (proposed by Ohtsu)

The topics regarding various phenomena in field and design are as follows:

Observation of deformation in front of the face by high sensitivity insertion type horizontal inclinometer (proposed by Iwasaki)

Core disking phenomenon (proposed by Saito)

Failure strain of rock and rock mass (proposed by Sakurai)

The present conditions of NATM and proposal to NATM design (proposed by Tanimoto)

New procedures relating to stress measurement in hydraulic fracturing (proposed by Mizuta)

Control work for stabilization on rock slope (proposed by Yasue)

The number of the general papers regarding rock mechanics published in the journal of this society is 4-5 each year. However, most of these papers have features and relate to the materials testing method and the properties of rock. Some of these papers report the study of anisotropy,

consolidation and fatigue failure of rock from the standpoint of probability, influence of stress rate on rock, creep properties of rock, various properties of rock at low temperatures, etc. Some general remarks discuss the contribution of rock mechanics to earthquake forecast techniques. That is, these papers supply the various fields handling rock as materials with the information required.

Dr. T. Saito, Secretary
Committee on Rock Mechanics, SMS, J.

II. ROCK MECHANICS ABSTRACTS

Rock mechanics abstracts consist of literatures on rock mechanics and related fields published in Journals and periodicals by Japanese Committee for ISRM and its organizing four societies; JSCE, JSSMFE, MMIJ and SMS, J.

The period for listing of this volume 4 is limited from the beginning of 1979 to the end of 1981.

The symbols, A–1, A–2, - - - S–3 which can be seen at the end of each Abstract correspond to I.G.C. classification symbols. The details are presented in Chapter III.

A. [General]

(1) Present Situation of Rock Mechanics

Iida, R.

Journal of the Japan Society of Civil Engineers, Vol. 66, No. 2, pp. 2-12, 1981,

Rock mechanics, dating back to the 1960 s, is of relatively new origin. This article will review its present situation, taking the opportunity that the International Rock Mechanics Symposium on Weak Rock will be held in Tokyo in coming September. Its recent development and future prospects are described together with the background of its growing importance and the circumstances of the organization of the Committee on Rock Mechanics in JSCE.

(A-7)

(2) History and Perspective of Underground Condition

Mizukoshi, T.

Tsuchi-to-Kiso, JSSMFE, Vol. 29, No. 1, pp. 5-10, 1981,

Recently, various underground structures such as underground powerstations in mountain districts, subways and underground markets in urban districts, have been constructed, and the scale is rapidly expanding. In Japan, which has small land and many earthquakes, the needs for underground structures having an advantage with respect to both land utilization and earthquake resistance, tend to increase. Underground structures such as underground fuel storage tanks and underground nuclear powerstation etc. are greatly anticipated.

This is the report on history and perspective of underground construction laying stress on structures concerning electric power, which the author has been participating many years.

(A-2, H-5)

B. [Engineering Geology]

(1) Characteristics of Construction Work of the Daiba Tunnel

Yokoyama, A. and Tottori, T.

Journal of the Japan Society of Civil Engineers, Vol. 65, No. 2, pp. 29-40, 1980,

An undersea tunnel of 5.7 km in length is now under construction across Tokyo Bay, where soft ground and ground subsidence make its construction work very difficult. Countermeasures against ground subsidence executed in this work are presented together with safety measures for navigation during construction.

(B-3, H-5)

(2) Investigation into Ground Condition by Use of the Satellite Images

Imaizumi, S. and Ueshita, K.

Journal of the Japan Society of Civil Engineers, Vol. 66, No. 10, pp. 9-15, 1981,

Information from the Landsat concerning the earth resources and environment possesses far-reaching, periodic and economical features. This article shows that the satellite image presents an effective means to investigate into the ground condition by an example that ground condition in the Chubu area is made out with naked eyes by the use of natural coloured composite images and black and white images taken eveny frequency band.

(B-9, C-1)

(3) Statistical Researches on Factors Affected Mountainslope Slides

Okimura, T. and Sugimoto, H.

Proceedings of the Japan Society of Civil Engineers, No. 290, pp. 89-97, 1979,

Mountainslope slides that occurred during heavy rainfalls take the shape of small and thin or shallow. Many factors which are considered to influence the occurrence of the slide are investigated in fields and are surveyed by the use of large scale maps, in the study, for the purpose to estimate the degree of influence of the factors upon the occurrence of the mountainslope slides.

A zero-order stream area which forms swale or linear depression in the mountainslope is employed as the analysis unit. 45 and 33 slopes are employed as failed and non-failed one respectively. Four factors are investigated in the every analysis unit and eight factors are studied by the large scale maps and aerial photographs. The contribution of the factors to the slope slides is obtained by the Hayashi's Quantification II that is one of statistical methods to discriminate.

The factors take the following order in discriminating between failure and non-failure: (1) slope gradient, (2) knick point, (3) vegetation, (4) surface microrelief type, (5) weathering, (6) minimum penetration value, (7) shape factor of analysis unit, (8) lineament and (9) history of failure. Especially, slope gradient, knick point and vegetation are found to be the most important factors in forecasting mountainslope failures.

(B-0, G-0)

(4) On Utilization of the Underground Space - With Special Reference to its Feasibility -

Yamamoto, S.

Tsuchi-to-Kiso, JSSMFE, Vol. 29, No. 1, pp. 11-14, 1981,

He reviewed the exotic use of underground open spaces. These are used for many purposes, especially for oil storage or for waste disposal site. Many kinds of abundant open spaces can accept and storage many "materials" but at the same time they can easily seep out to neighbouring places.

We should use these underground spaces carefully.

(B-2)

(5) Groundwater Dam In Miyake Jima of the Ryukyus

Kurokawa, M.

Tsuchi-to-Kiso, JSSMFE, Vol. 29, No. 1, pp. 1981,

The Ryukyu Limestone in Miyako-jima Island, which consists mainly of coral limestone covering bedrock of impervious mudstone, forms rich aquifers. But it has been unavailable for natural freshwater supply due to its high permeability. To make use of this groundwater flow, a groundwater dam was planned and completed in 1979 after two year's construction of the cutoff wall. With the estimated storage capacity of 7×10^5 m^3, the dam will serve for effective use of groundwater sources.

(B-2)

C. [Site Investigations]

(1) A Handy Method for In-Situ Bore Hole Shear Test

Kizawa, T. and Igarashi, T.

Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 11-15, 1979,

The authors developed a handy apparatus for bore hole shear tests which is applicable for in situ. After a bore hole with the diameter of fifteen centimeters has reached the planned depth, the bottom surface of the bore hole is ground flat. Then the cylindrical core of twenty-five more centimeters deep is cut, which is left in the bore hole and is tested. Shear force is applied by using a 10 ton jack, and is transferred by a pair of wedges and double tubes, under any normal load which is applied by using a 20 ton jack.

Shearing stress under normal stress n may be expressed as

$$\tau_s = \frac{Q}{S} = \frac{P \cot(2\lambda+\alpha)}{\pi r^2}$$

Where,

Q: Shear load,
S: Arear which carries the shear,
P: The force applied to push the wedge,
λ: Angle of friction between steel pieces,
α: Angle between the face of the wedge and the pushing direction.

Proof tests show that P to Q ratio is 1 to 2.7, from which λ and μ are derived as 7° and 0.13, respectively.

Some test results obtained at laboratory on cylindrical core specimens of tuff, coarse sand stone and mortar blocks are shown in figures. Obtained shear strengths are very close to those which are calculated from the tensile and compressive strengths of the specimens by using the method of least squares for the familiar Coulomb-Navier equation as follows,

$$\tau = \tau_0 + \sigma \tan \phi$$

(C-8, F-6)

(2) Development for Measuring Geo-Stresses Soft Rock-Masses and its Applications

Kanagawa, T., Hayashi, M. and Kitahara, Y.

Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 16-20, 1979,

In order to apply the over-coring method, which has traditionally been used and developed for hard rock, to such soft rock-masses as mud-stone, great consideration was given to improving the method.

(1) Drilling bit with a double-core tube (outer diameter 356mm, inner diameter 195mm) containing a core-cutter between the outer tube and the inner tube, is applied.

(2) A filling material is a mixture of cement milk and vinyl resin paste. This material has been found to stick securely to the surface of the mud-stone and was accompanied by a kind of penetration.

(3) Strips are placed at the intermediate position between the gauges set in the radial direction so that the filling material only plays a role as a medium which makes sure that the connection between the flanges of the gauge and the surface of the drilled hole of mud-stone are secure.

(4) For verification the procedures for the field test and analysis are simulated in the laboratory test with the aid of a bi-axial testing apparatus. In consequent, we found that the measurement of geo-stress within soft rock-masses like mud-stone can be performed.

(5) Based on these considerations, field measurement of geo-stress within rock-masses of mud-stone can be successfully carried out. It is concluded that the values of the principal stress are δ_3 = 13 kg/cm^2 in maximum compression and δ_1 = 11 kg/cm^2 in minimum compression.

(C-7)

(3) Relation between Borehole Load Lateral Test Results and Rock Properties in Granite Rock Mass

Saito, K., Kusunoki, K., Kiho, K., Takagi, H. and Isahai, H.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 1-5, 1980,

This report describes the results of the examination made on the relationship between borehole lateral load test results and rock properties in granite rock mass. The contents can be summarized as follows.

1) There was a clear correlation between rock grade and modulus of deformation. It was found that the better the rock grade the larger the modulus of deformation.

2) Between R.Q.D. (Rock Quality Designation) and modulus of deformation, it was recognized that the modulus of deformation increased exponentially with the rise of R.Q.D. ($\log y = 0.0114x + 3.6514$, $r = 0.71$).

3) The modulus of deformation of hard rock mass is known to be greatly affected by fissures in the rock mass. From this view point, the correlation between the number of fissures existing in rock mass and the modulus of deformation of the rock mass was examinated. As a result, it was found that the modulus of deformation decreased with increase in the number of fissures.

4) It was also recognized that the modulus of deformation obtained by borehole lateral load test increases with the depth of earth covering.

(C-8, F-6)

(4) Some Considerations of the Relations between Borehole Load Test and Geological Conditions

Takeuchi, T. and Suzuki, T.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 6-10, 1980,

Sometimes we have measured anomalous value which deviate from expected mean value of rock masses. It is important that we should extend the obtained point value to the mass evaluation. So that above mentioned anonalous value should beconsidered for that purpose.

Fourhundred and twelve points of borehole load test were measured on the granitic rock. Sixteen percent of that measured points are anonalous value. And about half of this sixteen percent are also anomalous value of geophysical logging which are caliper logging, electrical resistivity logging, density logging and reflection logging. Caliper and reflection logging show the good relation between borehole load test than other logging.

And relation between core aspect by drilling and borehole load test is as follows. Anomalous points of the borehole load test are corespond to following core aspect.

27.3% ——— sound core with no clack
31.8% ——— 〃 with vertical or oblique clack.
18.2% ——— short length and disking core.
4.5 % ——— weathered core.
18.2% ——— Small piece core.

This results show when we intend to measure the borehole load test, we should select the position with careful consideration, in case of which we have not much measuring points.

(C-8)

(5) A Trial in the Modeling of Joints Distribution in Granite Rock Mass

Kusunoki, K., Kikuchi, K. and Izumiya, Y.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 21-25, 1980,

This paper reports on the analysis of the properties of joints distribution and modeling of joints distribution in the foundation rock, using the method of quantitative evaluation of joints distribution developed by the authors. The results are described in this report which can be summarized as follows.

1) Measuring method of distributed joint properties

In the measurement of joints, with random sampling in mind, measuring points were selected on a grid system, and the measurement was made for a unit area of 10m x 10m or 1.5m x 1.5m at each of the measuring points.

2) Analyzing method of distributed joint properties

The authors analyzed the data using the "Analyzing method based on polar coordinates by the use of electric computer" developed by the authors. The program used in this case allowed the simultaneous statistical processing of the strikes, dips, lengths and intervals of individual joints, after they were digitalized into the computer.

3) Results of the analysis and modeling of joints distribution

In the surveyed area, there were four typical joint systems, viz. three continuous joints systems of (1) 165/85 (strike/dip), (2) 70/70 and (3) 135/85, and one almost horizontal and relatively short joint system of (4) 158/5.

A joint model is an approximate model made by combining and summarizing the data of joints distribution elements obtained by an analysis on such items as directions, continuity and density. The method proposed in this paper is summarized to facilitate the modeling of joints.

(C-9, G-0)

(6) An Example of Geological Site Investigation of Underground Storage Caverns for Fuels

Kikuchi, K., Motozima, I., Saito, K., Kondo, K., Kiuchi, T. and Shimada, J.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 46-50, 1980,

This paper outlines the geological site investigation at the small "I" island in the Seto Inland Sea, which is a planned site of the underground storage caverns for fuels. This investigation was done based on the "Technical Guides on Underground Storage Caverns for Fuels", which was prepared by Central Research Institute of Electric Power Industry (CRIEPI) and requested by Federation of Electric Power Companies (FEPC).

As a result of the survey, the followings were clarified.

1) "I" island is underlain almost by the Hiroshima granitic rocks of Cretaceous age intruded by porphyrite, aplite, etc.

2) In the survey area, the fractured zones strike almost north to south and lie in a parallel arrangement, so that the area investigated is divided into three blocks by predominant fractured zones named F5 and F6. The rocks of block I and II were subjected to hydrothermal alteration and became fragile. But the rocks of block III remain unaltered and show generally good geological conditions. This result has been endorsed by various well loggings in boreholes.

3) As for permeability of rocks in block III except the weathered layer existing near the ground surface, it is very small and almost equall. And the condition of ground-water is generally shallow and stable.

Thus, block III is assumed to be the most suitable in "I" island by its geological and ground-water conditions. Futhermore, through the geological investigation in "I" island, it was confirmed that the "Technical Guides on Underground Storage Caverns for Fuels" was reasonable.

(C-9,H-5)

D. [Soil Properties: Laboratory and Field Determinations]

(1) Tunnel Work Methods in the Shirasu Ground

Yamanouchi, T., Toshida, M., Nagano, M. and Takamori, A.
Journal of the Japan Society of Civil Engineers, Vol. 65, No. 4, pp. 28-35, 1980,

Shirasu which piled up by the eruption of volcanos prevails in the southern part of Kyushu. This article summarizes the characteristics of tunnel works in this poor ground of shirasu.

(D-5, H-5, K-11)

(2) A Study on Force Cutting Soil and Rock

Ishizuka, K.
Proceedings of the Japan Society of Civil Engineers, No. 307, pp. 39-50, 1981,

The cutting mechanism of soil and rock by using the flat cutter is 3 dimensional failure at the front of the cutter's edge. Cutting resistance, that caused in the primary failure that depends upon the movement of the cutter on condition that a cutting depth is constant, is defferent from the passive earth pressure founded on 2 dimensional theory of earth pressure.

As the cutting depth is deep in comparison with the blade breadth, the sphere of 3 dimensional failure is increase.

This paper deals with the cutting resistance at the primary failure on condition that the depth is constant. Soil and rock are used as the experiment materials.

According to the results of the model experiment carried out with several materials (sand, gravel and steel ball), the pressure distribution operating upon the width of the cutter

blade is higher in both edges than in center. That value in center of the cutter blade is higher than that given by 2 dimensional theory of plasticity.

The gradiant of that distribution depends on the angle of internal friction of the experimental materials and the value are determined by the 2 dimensional theory of plasticity.

This results applies very well in cutting resistance of the model experiment which deals with granular and clayey soil and mortal blocks.

(D-6, F-6)

E. [Analysis of Soil Engineering Problems]

(1) Series Solution for a Free Rectangular Plate on Elastic Foundations

Kitamura, Y. and Sakurai, S.

Journal of the Japan Society of Civil Engineers, Vol. 64, No. 3, pp. 61-66, 1979,

The solution for a rectangular plate freely supported on elastic foundations is given in terms of the series expression based on natural vibration modes. Its convergency is examined as for the deflection and contact pressure of a square plate, with a point load on its center, on the Winkler and the semi-infinite elastic foundations. The basic formulas are put in order for the convenience of use.

(E-8)

(2) Finite Element Analysis of Sheathing for Soft Ground

Aihara, I., Duncan, J. M. and Chang, C. S.

Journal of the Japan Society of Civil Engineers, Vol. 64, No. 12, pp. 41-47, 1979,

Cutting and sheathing of soft ground require reasonable prediction of ground condition. Nonlinear finite element analysis is here applied to this problem. Validity of the analysis and the effect of input data on the solution are discussed.

(E-2, E-3, E-6, G-4)

(3) An Application of the Freezing Method to Tunnels in Weathering Rocks - The Result of Test Pitting of the Fubiki Tunnel -

Murayama, S. and Ohno, K.

Journal of the Japan Society of Civil Engineers, Vol. 66, No. 10, pp. 25-30, 1981,

The freezing method is used to a test pitting of the tunnel in the weathering granite. The displacement of a bedrock and the earth pressure acting on timberings are measured before and after the freezing method is applied. The validity and applicability of the freezing method are examined.

(E-9, G-7, K-6)

(4) Effects of Basin Geology on River-Flow Regimes in Mountainous Areas of Japan

Musiake, K., Takahasi, Y. and Ando, Y.

Proceedings of the Japan Society of Civil Engineers, No. 309, pp. 51-62, 1981,

This paper discusses the dependence of river-flow regimes on basin geology for moutainous areas in the Japanese islands. Basin geology was classified into the following six categories ; Quaternary volcanic rocks, Tertiary volcanic rocks, Granitic

rocks, Tertiary formation, Mesozoic formation and Paleozoic formation, each of which has a wide distribution and a relatively high occurrence in mountain areas of Japan.

After selecting 46 stream catchments composed of uniform or quasi-uniform geological units, the authors investigated the relationship between their low-flow indicators equivalent to 355-day discharge and basin geology. The results show that low-flow indicator proves to be closely related to basin geology classified above and decreases from Quaternary volcanic, through Granitic and Tertiary volcanic rocks, to Mesozoic and Paleozoic formation.

A comparison was made among master recession curves for selected gauging stations with the catchment being typical with respect to the relative uniformity of geology. Recession patterns present a parallel trend according to the geological categories. With the help of the above examination of the relationship between low-flow indicator and basin geology, the smaller the indicator, the steeper the slope of the recession curve.

Quantification Analysis was applied for each of discharge values defined on annual flow-duration curve at 124 stations in terms of basin geology and climatic conditions. The partial correlation coefficient values obtained clearly demonstrate that the effect of climatic conditions is greater for such large flow as annual maximum, 35-day, 95-day, and annual mean discharge, while that of basin geology becomes more powerful for relatively small flow such as 275-day, 355-day and annual minimum discharge, and that the effects of both items are parallel for 185-day discharge.

These results mean that the natural capacity of groundwater storage and the natural effect of runoff regulation increases in mountain masses of Japan from Quaternary volcanic rocks, through granitic and Tertiary volcanic rocks, to Mesozoic and Paleozoic formations.

(E-7, G-5)

(5) A Study on the Non-Linear Characteristics of Unsteady Flow in Unconfined Aquifer

Ojima, M. and Adachi, K.

Proceedings of the Japan Society of Civil Engineers, No. 303, pp. 43-52, 1980,

This study is concerned with the non-linear response of the free surface ground water in a low land.
It is the purpose of this paper to investigate particularly on how far the influence caused by the difference of outer water level condition extends into the unconfined aquifer. Next, for the purpose of the quantitative estimation of unsteady characteristics of phenomena, the experimental results are compered with fundamental equations of unsteady seepage flow.

In the first place, the coefficient of permeability (k) and the effective porosity (λ) are considered as the functions of (x,t) and then following assumptions have been treated.
1) The flow occurs only depending on the difference of the water levels at the upper and lower boundaries.
2) The changes of outer water level (η_0, η_ℓ) are small enough in comparison with the initial water level (H_0) of aquifer and the seepage length is relatively long, so the seepage flow is treated as a quasi-onedimensional.

Non-dimensional fundamental equations are as follows:

$$\frac{\partial Y}{\partial T} = \frac{\partial^2 Y}{\partial X^2} + Y\frac{\partial^2 Y}{\partial X^2} + \left(\frac{\partial Y}{\partial X}\right)^2 \qquad (1) \qquad\qquad \frac{\partial Y}{\partial T} = \frac{\partial^2 Y}{\partial X^2} \qquad (2)$$

where, $Y = \eta/H_0$, $X = x/\ell$, $T = (kH_0/\lambda\ell^2)t$.
The difference quotient of Eq.(1) is expressed as Y_N and the one of Eq.(2) as Y_L, on the other hand non-dimensional amplitude of outer water fluctuation is expressed as A_η which means Max.$[\eta_0, \eta_\ell]/H_0$. And then, it has been considered to estimate the non-linearity of the fundamental equation by using the next proposed amount.

$$(Y_N - Y_L)/A_\eta \qquad (3)$$

For the typical fluctuation conditions, namely step-up condition at one end of boundary, set-up at both ends, periodical fluctuation at one end and periodical fluctuation at both ends, the non-linearities of Eq.(1) were calculated and thier

results were shown by the diagrams of non-linearity.

Generally, asthe value of η_0/H_0 increases gradually the value of non-linearity which is defined in Eq.(3) becomes more large. But, when the value of $\eta_0/H_0=A_2$ is less than equal 0.2, the value of Eq.(3) becomes less than 0.05～0.06. Therefore, it seemsthat the affect of non-linearity of Eq.(1) against the seepage phenomena is alittle. On other words, it can be concluded that the applicability of linear Eq.(2) is passably wide.

(E-7, G-5)

(6) Experimental Study on Rock Slope Stability by the Use of a Centriuge - A Study on the Stability of Rock Slopes (1st Report) -

Okamura, H., Sugawara, K., Akimoto, M., Kubota, S. and Kaneshige, O.
Journal of the Mining and Metallurgical Institute of Japan, Vol. 95, No. 1091, pp. 7-14, 1979,

The purpose of this paper is to study on the mechanism of failure of rock slopes by the model test through the use of the centrifuge equiped the apparatus for the strain measurement in models.

For the purpose of the theoretical study, the authors have first analyzed the elasto-plastic behaviors of rock slopes by the use of Finite Element Method and the results of this analysis have been compared with the experimental results of the model test. This comparison shows that the slide of rock slope occurs on a circular like plane and at the same time the tension crack breaks out behind the slope and this slope slide can be foreseen by the measurement of strain on the upper horizontal surface behind the slope. In the case of stable slope, this strain increment is compressive, but in the case of unstable slope, this is tensile. Moreover, it is found that the values of the stability factor, as determined by the elasto-plastic analysis, are respectively nearly equal to the results of the two dimensional limit analysis supposed slides on the circular arcs. Finally, the authors have analyzed the quantitative relation between the experimental results and the theoretical stability factors and concretely refered to the strain softning phenomena in the plastic area neighboring the toe of the slope.

(E-6)

(7) Characteristics of Surface Subsidence in Japanese Coal Mines

Okamura, H., Hiramatsu, Y. and Sugawara, K.
Journal of the Mining and Metallurgical Institute of Japan, Vol. 95, No. 1093, pp. 137-142, 1979,

In most coal mines in the northern district of Kyushu, precalculation of surface subsidence by the method developed in Germany was made for the purpose of investigating some possible way to minimize damages. On the other hand, surface subsidence had been measured in those mines for years, and even horizontal displacement had been measured in a few mines. However since the results of measurement had not been made open to the public, the actual state of subsidence in Japanese coal mines was not fully clarified. Recently the authors obtained fortunately the results of measurement of subsidence and horizontal displacement carried out in sixteen mines. From these data, the features of surface subsidence caused by mining inclined coal seams were made clear in comparison with those caused by mining horizontal seams.

The main features of them may be that the maximum subsidence is greater on the dip side than on the rise side and the former appears between the point just above the center of mined area and the intersection of the surface with the normal to the coal seam drawn from the center of mined area, and that the horizontal displacement is far greater on the dip side than on the rise side but the point of no horizontal displacement is found near the point just above the center of mined area.

The mechanism of the subsidence which shows such the features as described above was investigated by the gelatine model experiments and it was suggested that the phenomena of subsidence consisted in separation of the coal measures above the mined space followed by sagging and shifting of them towards the mined space.

(E-2)

(8) On the Mechanism of Caving-In due to Mining at a Shallow Depth (3rd Report) - Plasticoelastic Analysis by Finite Element Method -

Kameda, N. and Nishida, T.
Journal of the Mining and Metallurgical Institute of Japan, Vol. 95, No. 1096, pp. 331-336, 1979,

To study the mechanism of caving-in we have carried out experimental and theoretical analysis in the 1st and 2nd reports. On those analyses, the earth layer was idealized into homogeneous, isotropic and continuous material.

In this paper we defined that the earth layer was a perfectly plasticoelastic material and the mechanism of caving-in was studied theoretically by finite element method.

The results obtained are as follows.

1) Finite element method is a powerful method in order to study the mechanism of caving-in.
2) Caving-in has a tendency to occur with small cohesion, small angle of internal friction and large specific weight, large width of mining cavity.
3) When caving-in occurs, there is the limiting value for the relationship between width of mining cavity and the strength of earth layer.

(E-2)

(9) A Study on the Mechanism of Subsidence and An Improvement of the Precalculation of Subsidence - Surface Subsidence Caused by Mining Inclined Coal Seams (2nd Report) -

Okamura, H., Hiramatsu, Y. and Sugawara, K.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 95, No. 1102, pp. 865-870, 1979,

First, the mechanism of the subsidence of which features were described in the first report, was investigated by mathematical simulation using the finite element method. It was suggested that the phenomena of subsidence, caused by mining horizontal or slightly inclined coal seams, consisted mainly in separation of the coal measures above the mined space followed by sagging and shifting of them towards the mined space to fill it, in the order from the nether roof to the upper strata successively.

Secondly, the method of precalculation of subsidence developed in Germany, which is distinguished for the idea of an influence factor, was so modified that it could be adopted in case of inclined coal seams. The applicability of this modified method was examined by comparing the results of calculation with the measured results for several coal mines. It was found that by adopting this modified method the results of calculation would be much improved, though close coincidence of them with the actual subsidences was not attained as anticipated. Nevertheless this method of precalculation may be useful on account of convenience in mathematical treatment.

(E-2)

(10) On the Surface Subsidence in Natural Gas Fields

Nishida, T. and Aoki, K.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1115, pp. 13-18, 1981,

In natural gas fields, it is recognized that the surface subsidence is occured due to the pumping of gas-content-water. So, we studied characteristic behavior of subsidence and available prediction method of subsidence.

The analytical method we showed in this report mainly consists of two parts. One is the seepage analysis with finite element technique to obtain the plan-distribution of piezometric head in gas seams, the other is the calculation of subsidence using the above piezometric head, on the assumption that the ground behaves as a elastic material.

The following results were obtained:

The subsidence in natural gas fields is caused by the decrease of piezometric head in gas seams due to the extraction of gas-content-water, and the subsidence is proportional to the decrease of piezometric head.

And, it is found that the results of our analytical method very agree with those of actual measurements.

(E-2)

(11) On the Surface Subsidence in Natural Gas Fields (2nd Report)

Nishida, T. and Aoki, K.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1121, pp. 527-532, 1981,

This paper presents the prediction method for time-dependent development of the ground movements in natural gas field.

The analytical method we used is almost similar to that of 1st report. But, in order to take the time-dependent change of piezometric head in gas seam, Theis equation for unsteady flow to a well is used. It is found that Theis equation can be fully applied to 'gas well' and the calculated results agree well with the actual measurements.

And also, in order to take the influence of depth of gas seam upon the ground movements, finite element analysis is carried out.

So, the following results were obtained.

Increasing the depth of gas seam, the values of ground movements decrease, when the drawdown curve in gas seam is same in all cases.

The vertical ground movement (surface subsidence) which is given by our analytical method is slightly different from the profile with finite element technique, but it is sufficient to understand the outline of subsidence in natural gas field.

Finally, we find that the ground movements in natural gas field consist of the vertical and horizontal components. So, in natural gas field, we must consider not only the surface subsidence but also the horizontal ground movement.

(E-2)

F. [Rock Properties: Laboratory and Field Determinations]

(1) Time Dependent Characteristics and Constitutive Equations of Soft Sedimentary Rock (Porous Tuff)

Akai, K., Adachi, T. and Nishi, K.

Proceedings of the Japan Society of Civil Engineers, No. 282, pp. 75-87, 1979,

Now in our country, so-called soft rocks are distributed at the sites of such big civil engineering projects as Seikan Undersea Tunnel and Honshu-Shikoku Bridge constructions. In order to efficiently and successfully proceed those projects, it is immediate necessity to derive the constitutive equations for such soft rocks as half solidified sedimentary rocks deposited in Miocene Epock of Tertiary Period and strongly weathered granite. Generally, soft rocks are regarded as strain-hardening-softening plastic and rate sensitive materials with dilatancy.

The objective of this study is to clarify visco-elasto-plastic characteristics of soft sedimentary rocks in order to obtain more general and realistic constitutive equations for the materials. For the purpose, triaxial creep tests have been conducted by using Ohya-stone (porous tuff) deposited in Tertiary Period as an ideal soft sedimentary rock.

Throughout this study, the following conclusions are summarized: (1) critical stress is determined as stress corresponding to strain rate at steady creep state of 10^{-8}/min, which is called the static yield stress, (2) shear deformation below critical stress is regarded as the same as that of visco-elastic body. On the other hand, volumetric deformation is elastic, (3) soft rock shows the visco-plastic behavior with dilatant volumetric change above critical stress, (4) from the above mentioned experimental results, we derived the rate sensitive constitutive equations of soft rock based on the visco-elasticity and visco-plasticity theory.

(F-5, F-6)

(2) Mechanical Properties and Failure Criterion of Soft Sedimentary Rock

Adachi, T. and Ogawa, T.

Proceedings of the Japan Society of Civil Engineers, No. 295, pp. 51-63, 1980,

The mechanical properties of soft rock were investigated in laboratory tests by using porous tuff as an idealistic soft rock. Namely, triaxial compression tests were performed on intact rock specimens with confining pressures ranging from 0 to 200 kgf/cm^2. From the experimental results, we propose new failure criteria for both peak and residual strengths of intact rock.

In the test results it was found that the relationships between peak(and residual) strength and the mean effective stress is not linear. As a result, Mohr-Coulomb's failure criterion cannot fully apply. Assuming that there is partially a linear relationship, and if strength parameter c'(cohesion) and ϕ'(angle of internal friction) are determined by Mohr-Coulomb's failure criterion, these may give overestimated strength values. Moreover, since the relationship between stress and volumetric strain at the failure is not linear, it is desirable to obtain a condition which can describe both failure criteria.

Based upon above discussions, a new failure criterion is presented by the following two relations.

$$(q/p'_o) = \alpha(p'/p'_o)^{\beta} \quad (1), \qquad v = C\log(p'/p'_o) - v_o \quad (2)$$

where $q=(\sigma_1-\sigma_3)$, $p'=(\sigma'_1+2\sigma'_3)/3$, p'_o=1 kgf/cm^2(unit stress), and α, β, C and v_o are strength parameters. The strength parameters take different values at the peak or residual strength state. Note that the strength parameter α has a characteristic similar to cohesion c', since this can be regarded as the strength, q, when $p'=p'_o$= 1 kgf/cm^2. Whereas β is referred to the angle of internal friction ϕ' which varies with confining pressure.

(F-6, G-3)

(3) Applicability of the Bulk Compression Method to Crushers
Kiyama, H., Fujimura, H. and Oka, Y.
Proceedings of the Japan Society of Civil Engineers, No. 299, pp. 127-135, 1980,

As a basic solution of the problems of fine crushing by current equipments of crushed stone, the bulk compression method was proposed by the authors. The application of this method to the compression type of crusher, such as a jaw crusher and a cone crusher, is characterized by the much larger set of the bottom opening in the closed side than the ordinary set.

This method may increase the through-put of the crusher without essential decrease of the reduction ratio, and may result in increase of the anticipated fine products (e.g. the product size d_p=5-20mm for concrete aggregates in usual use) as well as the capacity of the crusher.

From the point of view, the laboratory bulk compression test was carried out, and the optimum conditions of fine crushing with high efficiency in the compression type of crusher and the ability of crushing to the desirable shape particles which strongly affect the quality of crushed stone, were discussed.

From the sieve analysis, the Zingg's diagrams, and the unit weight measurements, it becomes clear that the products tend to be cubic in shape and of high bulk-density, with decreasing the elongation ratio and the flatness ratio. Thus the bulk compression method may produce the desirably shaped stone for the use of concrete and road constructions.

From the crushing energy analysis, it also becomes cleare that the increase of numbers of strokes with reducing the energy input per each stroke can arrive at the higher efficiency of crushing energy. These optimum conditions in the bulk compression test may be achieved in actual crushers by the larger discharge-set, the less length of stroke, and the higher rate of stroke motion.

Most of the results above-mentioned have been confirmed by the small jaw crusher run.

(F-6, K-0)

(4) Effects of Joints on Mechanical Properties of Soft Rocks
Adachi, T. and Hayashi, M.
Proceedings of the Japan Society of Civil Engineers, No. 305, pp. 97-110, 1981,

Even for soft rocks, material actually considered is rock mass with discontinuous planes such as fissures and joints. It is less possible that an intact rock itself is of interest.

After the intact rock specimen fails under confining pressure lower than the transitional stress of the material, it reaches the residual strength state with further shear deformation. A single shear plane occurs, and the specimen is sliding along this plane.

In other words, the residual strength state may be considered to reflect the case where the mechanical behavior of the material is entirely dominated by discontinuous plane. Therefore, the strength in this stage may coincides with the minimum strength of the rock mass with discontinuous planes. Namely, it can be seen that the upper bound of the rock mass strength corresponds to intact rock strength, whereas the lower limit is bounded by the residual strength, and that the rock mass strength in the field lies at least within these linits.

In order to confirm this point of view for rock mass strength as well as ideally simulate and make clear the mechanical behaviors of rock mass consisting of intact rocks and discontinuous planes, triaxial compression tests were carried out on specimens each of which had a saw cut plane with various angle to the maximum principal stress plane.

The main experimental evidences found through this study are as follows:

(1) Under confining pressures lower than the transitional stress of the material, the stress-strain relations are affected by existence of and the angle of a saw cut plane, whereas confining pressures greater than the transitional stress, the mechanical behaviors do not depend upon the existence of a saw cut plane.

(2) The peak and residual strength criteria for the specimen with a saw cut plane are given by the following relations.
For peak strength,

$$(q/2\ \sigma'_{no})_{peak} = \alpha^*_p(\sigma'_n/\sigma'_{no})^{\beta^*_p}$$

For residual strength

$$(q/2\sigma'_{no})_{residual} = \alpha^*_r(\sigma'_n/\sigma'_{no})^{\beta^*_r}$$

in which $q = (\sigma_1-\sigma_3)$, $\sigma'_n = (\sigma'_1+\sigma'_3)/2$ and σ'_{no} is a unit stress(1 kgf/cm^2), and the strength parameters α^* and β^* for the peak strength are functions of the angle of the saw cut plane, but $^p\alpha^*_r$ and $^p\beta^*_r$ for the residual strength take approximately constant values.

(F-6)

(5) Multiple Stage Triaxial Test and its Application to Fully Saturated Soft Rock

Akai, K., Ohnishi, Y. and Lee, D.

Proceedings of the Japan Society of Civil Engineers, No. 311, pp. 93-102, 1981,

Triaxial compression test is one of the well-known test methods to characterize the mechanical behaviors of rock-like materials in a laboratory. But, only one pair of strength parameters (peak and residual strength) can be obtained from a specimen by this conventional method. Therefore, it is very inconvenient in achieving the whole spectrum of mechanical characteristics of rock while the amount of rock specimen is so limited due to the geological conditions, etc..

Kovari and Tisa (1975) have proposed a plausible and economical triaxial shearing test method for hard rock, designated as the Multiple Failure State Triaxial Test. Then, more sets of strength parameters and the full range of strength envelopes can be deduced by using only a few specimens.

However, this method is not adequate for saturated soft rock, due to the excess pore water existing in rock specimen while shear test is being underway.

After a series of improving experiments, the Multiple Stage Triaxial Test for saturated soft rock is induced. It consists of three items as follows:

1. In each stage, consolidation process has to be done before the shearing of specimen is carried out.
2. To prevent an unexpected abrupt failure, unloading of the axial load must be performed as soon as possible when the stress of the specimen is near to the peak.
3. It is recommended that confining pressure should be changed from a lower value to a higher one in a series of MST.

Furthermore, the MST for soft rock is also applied to investigate the mechanical behaviors of soft rock with artificial discontinuity and detect the influence of discontinuity on the peak strength and residual strength of soft rock.

(F-5, F-6)

(6) Source Mechanisms of Acoustic Emission

Niwa, Y., Kobayashi, S. and Ohtsu, M.

Proceedings of the Japan Society of Civil Engineers, No. 314, pp. 125-136, 1981,

Acoustic Emission, which is abbreviated as AE, is the transient elastic wave that is spontaneously emitted when materials undergo deformation, fracture, or both. In oder to clarify mechanisms responsible for AE phenomena in rock-like materials such as concrete and rock, where the creation and running of cracks are proposed as major sources, it may be required to study relations between source mechanisms and wave motions of AE.

In this paper, we study theoretical representations of AE waveforms in concrete and investigate source mechanisms of AE by experiments.

To study wave propagations in a half space, we used finite plates of mortar and concrete. AE wave motions generated by two kinds of point forces, which are called the surface pulse and the buried pulse of Lamb's problem, were detected. They were simulated theoretically by use of the dislocation theory and Green's functions. A good agreement between the computed waveform and the detected AE waveform was seen in most respects of the initial part of wave motions.

AE waves due to two basic types of fracture mechanisms, which corresponds to a tensile crack and a shear crack, were generated by the split tests and the punching shear tests, respectively. They were also simulated on the basis of the dislocation theory. The computed waveforms were in good agreement with the detected AE waveforms. These results verify an applicability of the theory of the elastodynamics and the dislocation to investigate source mechanisms of AE.

(F-6)

(7) Frequency Spectra of Acoustic Emission

Niwa, Y., Kobayashi, S., Ohtsu, M. and Okuda, K.

Proceedings of the Japan Society of Civil Engineers, No. 314, pp. 137-147, 1981,

Acoustic emission (abbreviated as AE) is defined as the transient wave emission phenomenon or the emitted wave itself caused by a spontaneous release of energy when materials deform and/or fracture.

In this paper, we clarify the signal flow process of AE waveforms in the frequency domain by use of the theory of linear system. Since the mechanical-electrical conversion property of linear piezoelectric materials is known, the eigen-value analysis of the transducer employed were carried out by the axisymmetric finite elements. Results show that the transducer has only the first resonant frequency in the detecting frequency range and the vibrating mode corresponding to the first resonance is of a thickness compression mode.

The theory based on the linear system was applied to investigate the frequency response of the transducer and examined by experiments. From these results, the calibration technique of the frequency response of the transducer was discussed and developed. We applied this technique to AE waveforms of the same event. A good correlation between the frequency spectra of two waveforms was obtained.

The source mechanisms of AE were classified into two groups by the radiation pattern of P-wave. They are associated with tensile cracks and others. Then the calibrated spectra of AE waveforms were obtained from uniaxial compression tests, split tests, and bending tests of reinforced beams in concrete and mortar. Results show that frequency contents of AE waveforms are related to mechanisms which produce it and ray paths passing through a medium. From consideration in respect to types of source mechanisms, it is shown that AE waveforms generated by tensile cracks have the prominent peak at a low frequency range, and frequency spectra of AE waveforms due to other mechanisms are relatively flat between an analyzed frequency range.

(F-6)

(8) Numerical Method on the Underground Containment of Fission Products at a Hypothetical Accident in Underground Nuclear Power Plant

Komada, H. and Hayashi, M.

Proceedings of the Japan Society of Civil Engineers, No. 288, pp. 115-126, 1979,

As one of means to expand the siting of nuclear power plant, construction of underground nuclear power plant is now under study. An underground nuclear power plant has a feature that surrounding ground of the underground cavity can contain the fission products at a hypothetical accident.

If it is supposed, in a hypothetical reactor accident, that the cooling system loses its capacity wholly or partially, then gas containing fission products will be emitted into the underground cavity. As a result, temperature, gas concentration and atmospheric pressure in the cavity will increase and it can be supposed that the gas leaks up to the ground surface through ground from the cavity and that groundwater containing dissolved gaseous and non-gaseous fission products carries them. The present paper numerically simulates such a course of movement as mentioned above by the finite element method and gives on the appraisal method of the underground containment effect for fission products at a hypothetical accident in underground nuclear power plant.

It may be assumed that fission products to be appraised from the standpoint of safety at an accident in underground nuclear power plant are iodine and noble gases only. It appears that among iodine and noble gases which leak from the containment vessels, fission products to be investigated first of all are those of comparatively long half-lives: ^{131}I with its half-life 8.07 days and ^{85}Kr with 10.76 years.

Based on an analysis of the movement of ^{131}I and ^{85}Kr in gaseous phase above the groundwater table at a hypothetical accident, the maximum credible accident of primary coolant loss, on the assumption that the thickness of earth covering above the underground cavity is 30 m and the covering is composed of such rock mass as often observed on coastal hillside slope in Japan, the following results have been obtained:

Iodine is a fission product, of which adsorption on solid phase in the ground can be expected. It can be said from the analysis that the quantity of ^{131}I which leaks away in the atmosphere through the ground from an underground nuclear power plant decreases down to about $1/10^5$ as low as that from a corresponding on-ground plant.

On the other hand, noble gases are fission products, of which adsorption on solid phase in the ground cannot be expected. However, it can be said from the analysis that the quantity of ^{85}Kr which leaks away in the atmosphere from an underground nuclear power plant decreases down to about $1/10^2$ as low as that from a corresponding on-ground plant. It appears that the thickness of earth covering above post of actual underground cavities exceeds 100 m. Consequently, it can be predicted that the actual underground containment effect for fission products can be still higher than the above-mentioned results.

(F-8, G-5)

(9) Experimental and Numerical Studies on the Bearing Capacity of Soft Rock Foundation

Yoshinaka, R. and Nishimaki, N.

Proceedings of the Japan Society of Civil Engineers, No. 304, pp. 113-128, 1980,

The bearing capacity and settlement of structural foundation on soft rock are very complicated due to the presence of fault and other discontinuity in foundation rock, and non-linear properties of deformation behaviour and failure condition of soft rock.

This report presents the results obtained from (1) the experimental study about the load-settlement behaviour of a rigid footing on the model rock foundation with a fault placed at various distances

from the center of footing, and (2) the numerical analysis by FEM. And another case study used the same procedure is described, that is, the result of in-situ loading test on weatherd granite, and its numerical analysis.

The experimental studies show the remarcable influence of the presence of a fault and the mechanical characteristics of soft rock to foundation behaviour. And it is shown that the failure wedge in foundation rock beneath the footing is always formed and the shape and size of wedge largely change in relation to the position of fault.

The mathmatical models of soft rock and fault for numerical analysis are as follows;

(1) Non-linear deformation behaviour of soft rocks expressed by tangential elastic moduli used hyperbolic function (Duncan and Chang 1970, Kulhawy and Duncan 1969), and softening behaviour from peak to residual stress considered.
(2) Non-linear failure condition expressed by power function criterion (Yoshinaka and Yamabe 1979) and modified bi-linear Coulomb- Mohr failure condition.
(3) Joint normal and shear stiffnesses to express fault deformation.

From the comparison of experimental and numerical results on the bearing capacity and load-settlement behaviour, it is concluded that the calculated results approximately agree with that of experimental results, and therefore the analitical method adopted in this study seems to be useful to practical problems.

(F-5, F-6, G-3)

(10) Evaluation of Rock Properties by a Handy Seismic Timer

Saito, K., Kusunoki, K. and Kikuchi, K.

Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 1-5, 1979,

Lately various simple instruments for measuring the velocity of elastic waves have been developed.

These instruments, which are handy and easy to operate, are applicable to measurement and evaluation of rock, when speedy result is required, for instance, at the site of construction.

This paper describes a study on an application of ES-100 Signal Enhancement Seismograph which was developed by Nimbus Instruments Ltd. in U.S.A., for the measurement on rock foundation.

(1) Comparing the velocities of elastic waves measured by Seismograph with those obtained by the conventional seismic method, the accuracies of the two values proved to be almost the same.
Since the velocity of elastic waves measured by Seismograph is obtained by the method in which the measurements are conducted only by setting a geophone as well as a shot point on the rock surface, Seismograph is more effective than the conventional method in the light of speedy measurement on loosing areas around the caverns.

(2) A close correlation was ascertained between the velocity of elastic wave by Seismograph and modules of deformation, and also between the velocity and the modules of elasticity, which are often used in designing civil engineering structures.
As a result, in view of the possibility that the order of physical constant throughout the foundation is estimated continuously, Seismograph may be judged as convenient and effective, when speedy result is required, for example, at the site of construction.

(3) A good relationship was also found between rock grades and the velocity of elastic wave by Seismograph. More objective judgement may be possible on the classification of rock grades, which are related to the physical constants of rocks.

(F-1)

(11) A Correlation between Rock Grades and In-Situ Shear Test
Kusunoki, K., Kikuchi, K. and Saito, K.
Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 6-10, 1979,

This paper describes a correlation between rock grades and the result of in-situ shear test.

It was found that there exists a correlation between rock grades and values of shear strength. The better the rock grade is, the higher the shear strength.

According to our data, the cohesion and the angle of shearing resistance of each grades is as next ranges.

D class ; under 5kg/cm^2, under 15°
C^L class ; 5 ∿ 10kg/cm^2, 15 ∿ 38°
C^M class ; 10 ∿ 24kg/cm^2, 38 ∿ 45°
C^H class ; 24 ∿ 40kg/cm^2, 45 ∿ 55°
B class ; 40 ∿ 60kg/cm^2, 55 ∿ 65°

These results make it possible to estimate the rock static constant of mechanical properties from rock grades, and it can be found applicable for the evaluation of whole rock by in-situ rock test.

(F-1, F-6)

(12) Strength Criteria and Scale Effect of Soft Rocks
Yoshinaka, R. and Yamabe, T.
Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 31-35, 1979,

Strength criteria for peak, residual and yield strengths, can be expressed with the following equation by the normalized power law;

$$\tau_m / \tau_{mo} = \alpha (\sigma'_m / \sigma'_{mo})^{\beta}$$

, where $\tau_m = (\sigma_1 - \sigma_3)/2$, $\sigma'_m = (\sigma'_1 + 2\sigma'_3)/3$, τ_{mo} and σ'_{mo} are the case of $\sigma'_3 = 0$. α and β are material constants for rocks. Each values are shown in Table 1.

This equation can be widely applied for various rocks such as over-consolidated clay, silty clay, mudstone, limestone and so-on as shown in Figs. 2 and 4-8. The unconfined compressive strength of these rocks takes from 2.1 kg/cm^2 to 2670 kg/cm^2.

In order to investigate the behaviour of dilatancy during shear process, triaxial compression tests used the sample size of 100 mm dia., 200 mm length and 50 mm dia., 100 mm length are carried out under the condition of consolidated-drained test. The stress-strain behaviours are shown in Figs. 11 and 12 respectively. From this experiments it is clarified that there is no difference in residual strength between

Ø100 mm and 50 mm samples, however, peak and yield strengths of Ø100 mm sample are decreased by approximately 10-20 % compared with that of Ø50 mm sample. It seems that the failure is confined to thin slip zone in the stress lower than the preconsolidation or yielding pressure, and volumetric change is influenced by the scale effect.

(F-6)

(13) Suggested Method for Determination of Slaking-Index by Simple Test

Yoshinaka, R., Kojima, K. and Tanaka, S.

Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 36-40, 1979,

We propose a simple method for Determination of Slaking Index in this paper.

This method has been discussed in relation to the works to standardize some tests for soft rocks at the Commitee of Rockmechanics, Japan Society of Civil Engineers.

This simple test is based on the observation of the extent of disintegration of soft rock immersed into water after desiccation. The Slaking Index is ranked in 5 grades (no slaking to completely muddy) according to the extent of disintegration.

This test should be tried as the first step to know whether we should have more precise tests or not to estimate some problems for slaking and swelling in construction works.

(F-2)

(14) Strength Characteristics and Failure Criterion of Soft Sedimentary Rock

Adachi, T. and Ogawa, T.

Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 41-45, 1979,

Now in our country, so called soft rocks are distributed at the sites of such big civil engineering projects as Seikan tunnel and Honshu-Shikoku bridge constructions. In order to efficiently and succesfully proceed those projects, it is immediate necessity to make clear the mechanical properties of such soft rocks as half solidified sedimentary rocks deposited in Miocene Epock of Tertiary Period.

The objective of this study is to show the strength characteristics of soft rock and propose the new failure criterion for the material. For the purpose, triaxial tests have been conducted by using Ohya-stone(porous tuff) deposited in Tertiary Period as an ideal soft sedimentary rock.

Throughout this study, the following failure criterion for the material is proposed.

Peak Strength:

$(q/p_o')_{peak} = \alpha_p (p'/p_o')^{\beta_p}$ when $p' <$ pre-histrical pressure

$v_{peak} = C_s \log(p'/p_o')$

$(q/p_o')_{peak} = (q/p_o')_{residual}$ when $p' >$ pre-histrical pressure

$v_{peak} = v_{residual}$

Residual Strength:

$$(q/p_o')_{residual} = \alpha_r (p'/p_o')^{\beta_r}$$

$$v_{residual} = C_r \log(p'/p_o') - 12.3 \quad (\%) \quad \text{when} \quad p' < \text{pre-histrical pressure}$$

$$v_{residual} = C_c \log(p'/p_o') - 22.1 \quad (\%) \quad \text{when} \quad p' > \text{pre-histrical pressure}$$

where

$$p' = (\sigma_1' + 2\sigma_3')/3 = \sigma_m', \quad q = (\sigma_1' - \sigma_3')$$

(F-6)

(15) Experimental Studies on Swell Creep Behavior and Mechanical Properties of Soft Rocks

Ito, T.

Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 46-50. 1979,

This is a report of an analytical and experimental researches to fill an important role in the field of swelling phenomena.

One dimensional swell tests and compression tests were performed to grasp the characteristics of swell creep behavior and uniaxial strength properties on raw bentonite rock (B-rock) and artificially compacted specimens (B_{10}, B_{20}, B_{25}, B_{30}, B_{50}), as soft rocks, of Kunimine bentonite.

A constitutive equation on swelling pressure which is previously proposed by the author was reviewed with B-rock, and there was reasonable agreement between the measured swelling curve and the analytical one.

Swelling behavior during unloading increments in the ordinary oedometer apparatus is highly affected by overconsolidation ratio(OCR). The influence of OCR on the swelling curves of B_{50} was remarkable than the natural rock(B-rock), and it was essentially dependent with clay-water system. Time-rate of swelling and softening tends to increase with OCR. Comparing with the theory proposed by Mitchell et al, the increasing strain rate is not always sufficient for all over the test range. Thus the effect of OCR on the time-rate-swelling relationships is still required further investigation.

From the results of uniaxial compression tests on artifitial soft rocks, the envelopes of peak strength were demonstrated that the strength properties with bentonite content variables were classfied into three types. A general description to the peak strength model of the clay-water content dependent behavior of soft rocks was proposed by combining the concept of transient saturation, which is more profitable than the water content concept.

(F-5)

(16) A Fundamental Study on Underground Storage of Liquefied Natural Gas, - Characteristics of Rocks at Low Temperature -

Inada, Y. and Yagi, N.

Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 86-90, 1979,

One of the problem of underground strage of L.N.G. is a rock stability at low temperature or after having been at low temperature.

In this study, the physical and the mechanical properties of rocks which had been at low temperature of 0, -40, -80, -120, -160°C are

investigated. But every sample was at normal temperature during the physical and the mechanical tests.

Main results obtained are as follows :

1) Both the compresive and the tensile strength of these rocks are smaller than ones of the rock which had not been at low temperature.

2) Increase of micro cracks of the Granite with falling temperature which was guessed from the test results of the Young's modulus and the Poisson's ratio, was observed by the microscope.

3) The results of the X-Ray diffraction show that cracks seem to be grow between Quartz and Biotite, and between Quartz and Albite in the Granite and the Andesite.

(F-8)

(17) On a Method of Evaluation of Rock Creep Property

Akagi, T. and Mizutani, Y.

Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 91-95, 1979,

It is convenient that use the rheological models to analyze the time dependent behaviour of rock-ground. But we must recognize that the analytical results depend on the model constants. Therefore, studying the method of evaluation of the model constants is important.

Many rheological models have proposed from ancient times. Maxwell, Voigt, Zener and Burger used Original models to interpret the behaviour fo viscoelastic materials. These models represent the restricted behaviour of viscoelastic materials, but can not represent the general property of the materials.

The generalized rheological model is convenient to explain with physical significance the creep property. This paper propose a method of evaluation of creep property based on the generalized rheological model. In the result, the creep property of rock is interpreted by the indexes J_0, J_i, T_i ($i=1,2,\cdots,n$) and number n. J_0 means instantaneous response. T_i is retardation time of i-th creep mechanism and J_i is its intensity. n is number of creep mechanism.

(F-6)

(18) Model Experiment on Characteristics of Deformation of Rocks by Borehole Load Test

Miyajima, K., Ochi, K., Takeuchi, T. and Suzuki, T.

Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 96-100, 1979,

This paper describes results of model experiments of the borehole load test. Specimens of the model test are natural rocks and the size of each specimen is 60cm wide 60cm long and 120cm heigh.

One aim of this test is to study the effect of overburden on the deformation modulus obtained by the borehole load test. As the result, it is found that the deformation modulus measured by borehole load test is strongly affected by the overburden. Therefore, when the thickness of overburden is diminished by excavation, it is suggested that the deformation modulus of rock may possibly decrease.

Another aim of this test is to measure the strain distribution in the radial direction of the specimen caused by the borehole load. As results, it is found that the outword decrease of strain from the wall of borehole is not equal to the result calcurated by the elastic theory. The distribution of strain as a function of radial distance is expressd by $\frac{1}{r^{3.5}}$

This result indicates also that the deformation of rock by the borehole load is much affected in the neighborhood of the borehole wall. Therefore, when a borehole load is applied the borehole for the test should be so carefully drilled as not to disturb the borehole wall.

(F-6)

(19) Deformation Behavior and Failure Mechanism of Rock in Borehole Loading Test by Pressiometer

Hata, S., Tanimoto, C. and Nishihara, A.

Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 101-105, 1979,

It is needed to obtain the elastic properties of rock in-situ for more precise design of structures on rock mass. The borehole loading test, which was originaly established in the field of soil mechanics, is one of the methods of determining the in-situ elastic properties of rock mass. In recent years this method has been widely used because of its simplicity, low cost and wide applicability, but it has not been fully established.

The analysis of the borehole loading test is based on the theory of elasticity. But in most cases the rock mass contains fractures which are expected to have large effect on the deformability. Therefore, it is important to clarify the applicability of the borehole loading test on rock mass with fractures. As a first step of the research projet, the borehole loading tests were carried out on the rock model in the laboratory to clarify the applicability of the borehole loading test on the rock without fractures.

The model rock masses were made of mortar and gypsum, and it was encased in a drum to confine its lateral deformation. To obtain the deformation characteristic of the rock mass, stress gages were placed in tangential, radial and vertical directions in the mass. The cyclic loading tests using the pressiometer, which is one of the borehole loading test apparatus, were carried out, and strain was also measured to each pressure.

From the results of loading test, it is shown that the rock mass without fracture behaves as an elastic body and in such a case the borehole loading test has good agreement with the deformation of the rock mass. If the pressure is increased till the borehole wall are fractured, the results of the borehole loading test are affected with the fracture and the method now in use is not applicable.

(F-6)

(20) Experimental Studies on the Size Effect of Brittle Materials

Tano, H. and Satake, H.

Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 116-120, 1979,

This paper proposes to a statistical model of the size effects that is composed of parallel chains each other. It is assumed that the number of these chains are corresponded to the dimensions of the length of specimen, and also the number of links composed of singl chain to its diameter.

If these assumptions hold, as the length increases the strength of specimen increases, that is, the strength increases as the volume increases depending on the ratio of diameter to length of specimen.

Based on this assumptions, the size effects of the uniaxial compressive and radial compressive strengths are given in the equations (8), (9) and (10).

In oder to confirm these results, it was experimented that uniaxial and radial compression tests of cylindrical specimens by plaster changed of its size as follows;

Case A(Fig.5,8); The length(h) of specimen is variable without altering its diameter(d).

Case B(Fig.6,9): The diameter(d) is variable without altering its length(h).

Case C(Fig.7,10): The ratio of diameter to length is kept constant.

The experimental results which were obtained in the way described above are shown in Fig.6 - 10. These experimental results shows a similar tendency to this consideration.

(F-6)

(21) An Experimental Study on the Probabilistic Model of the Compressive Strength of Brittle Materials

Tano, H. and Satake, M.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 11-15, 1980,

It is well-known that the size effect of brittle materials is explained by the so-called weakest link theory. It is considered, however, that this theory is still insufficient to discuss the reason why the strength depends on the ratio of the length of specimen to its diameter.

In this paper, the probabilistic model for the compressive strength composed of many chains as is shown in Fig.(1) is proposed in order to take into account not only the size effect but also the ratio of length to diameter. It is assumed here that the number of these chains corresponds with the length of specimen and the number of links composed of a chain corresponds with the diameter. Such model makes possible to take into consideration the effect of the number and distribution of flaws in a specimen. The relations between the chain number k and the length h of a specimen and between the link number r and the area S of the cross-section are obtained from the observation of crack length in the cross-section of specimens under compression test.

The obtained equations are written as

$$r = A \cdot h^{\frac{1}{3}} \quad , \quad r = B \cdot S$$

where A and B are material constants listed in Table 2.

The estimated values of compressive strength from Eq.(2) show a good agreement with the experimental values as is shown in Fig.(7).

(F-6)

(22) A Failure Criterion of Rocks and Rock Masses

Yoshinaka, R. and Yamabe, T.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 16-20, 1980,

The paper presents the results of investigating the applicability of a failure criterion by power function (Yoshinaka, R. and Yamabe, T., 1979), to the failure conditions of rocks and rock masses.

The failure criterion expressed by power function is as follows:

$$\tau_m / \tau_{mo} = \alpha (\sigma'_m / \sigma'_{mo})^{\beta} \qquad \text{----- (1)}$$

, where $\tau_m = (\sigma_1 - \sigma_3)/2$, $\sigma'_m = (\sigma'_1 + \sigma'_2 + \sigma'_3)/3$, τ_{mo} and σ'_{mo} are the case of $\sigma'_3 = 0$. α and β are material constants of rocks and rock masses.

It is clarified that this equation (1) can be applicable to the following conditions.

i) States of stress at tensile failure under radial compression (so-called Brazilian test) and confined radial compression. With the same material constants obtained from triaxial compression tests, as shown in Figs. 1 and 2.

ii) Strength reduction by scale effects. Only by considering the unconfined compressive strength and equation (i), as shown in Figs. 3 and 4.

iii) Strength anisotropy varied with angles between discontinuities and principal stresses. As shown in Figs. 6-8 and 14.

iv) Strength relation of closely jointed rocks as the model of rock masses. As shown in Figs. 9-12.

v) Strength relation of true triaxial stress conditions. As shown in Figs. 13 and 14.

(F-6)

(23) Effects of Ground Water and Heavy Oil on Frictional Strength of Rock Joints

Tokue, T., Hayashi, M. and Kitahara, Y.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 26-30, 1980,

It is important to increase an amount of liquid fuel in stock for constant and sufficient supply of electric power. Countermeasure against calamities demands an rapid development in technique for underground storage of liquid fuel instead of a tank on the ground. For this purpose, shearing tests are conducted with rock pla-

tes of granite and tuff and crushed stone in oil and in water by using a large-scaled box shear machine.

Rock plates which are cutted by a diamond cutter and are cracked along inherent joints by force are used as joint planes. These plates are soaked in water or in heavy oil for 3 to 40 days.

As a result, it is clarified that the frictional strength of rock plates is smaller by 20 to 25 percent in the state soaked in water or heavy oil than in the dry state.

(F-6)

(24) Effects of Joints on Mechanical Properties of Soft Rocks

Adachi, T. and Hayashi, M.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 66-70, 1980,

Since even for soft rock mass they contain the geological discontinuities, it is required to clarify the effects of the discontinuities on the mechanical properties of soft rock mass. In order to ideally simulate the mechanical behaviors of rock consisting of intact rocks and discontinuities, triaxial compression tests are conducted by using specimens each of which has a saw cut plane with various angle α to the maximum principal stress plane.

Throughout this investigation, the following conclusions are summarized.

(1). Under the confining pressure less than the prehistrical pressure, the stress-strain relations are affected by the existence of discontinuity and the angle α between the discontinuity plane and the maximum principal stress plane. When, however, the confining pressure becomes higher than the prehistrical pressure, the mechanical behaviors do not depend on the existence of discontinuities.

(2). The shear modulus G changes the value with the angle of discontinuity, but the balk modulus K is not so much influenced by the angle. The elastic moduli of the specimen having discontinuity are smaller than of the intact rock specimen, but the values remain in the same order.

(3). When the confining pressure is less than the prehistrical pressure, the peak strength value changes with the angle α and takes its minimum value for the angle $\alpha=60°$. The residual strength, however, is not influenced by the existence of discontinuity and has the same value of the residual strength of intact rock specimen. The peak strengths of the specimens with discontinuities lie between the peak and residual strengths of the intact rock as the upper and the lower bound, respectively.

(4). The peak and residual strength criteria for the specimens with discontinuities are given as following relations.

For peak strength

$$(q/2\sigma'_{no})_{peak} = \alpha^*_p(\sigma'_n/\sigma'_{no})^{\beta^*_p}$$

For residual strength

$$(q/2\sigma'_{no})_{residual} = \alpha^*_r(\sigma'_n/\sigma'_{no})^{\beta^*_r}$$

in which $q/2 = (\sigma'_1-\sigma'_3)/2$, $\sigma'_n = (\sigma'_1+\sigma'_3)/2$ and σ'_{no} may be say 1 kg/cm^2.

The material constants α^*_p and β^*_p for the peak strength are functions of the discontinuity angle α, but α^*_r and β^*_r for the residual strength take approximately constant values.

(F-6)

(25) Laboratory Experiments of Hydraulic Fracturing on Permeable Soft Rock

Akai, K., Ohnishi, Y. and Yashima, A.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 71-75, 1980,

Hydraulic fracturing technique has recently been used worldwidely to determine the in-situ stress in the earth's crust. Most of the works deals with the hard impermeable rock mass and therefore the theories are built to suit for such rock. However, in Japan, we often encounter the permeable soft rock mass which usually causes a lot of trouble in construction work. The in-situ stress determination in such soft rock mass has been hoped to ease the design and analisis of rock structures. Stress measurement in soft rock is not easy because it is often saturated and so is difficult to use strain gauges. Feasibility study that the hydraulic fracturing technique may be or may not be applied to soft rock (mudstone, for example) was done in a modified triaxial cell. The mechanical behavior of soft rock due to injection of pressurized water was also investigated. Vertical and also horizontal fracutres were created in the cell under the various stress conditions. Flow rate and pressure increase rate in the drilled hole were found to be very influencial to the generation of fracture and fracture orientation.

(F-6)

(26) Mechanical Behavior of Soft Rock in Multiple Stage Triaxial Test

Akai, K., Ohnishi, Y. and Lee, D.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 76-80, 1980,

Test results on the validity of the multiple stage triaxial test for the determination of strength parameters (peak and residual) of water saturated soft rock are presented. The strength parameters obtained from MST tests were compared with those evaluated by single stage triaxial tests, and it was shown that the MST tests is valid and applicable to saturated soft rocks if the stress path in the triaxial test is adequately chosen.

The saturated rock behaves differently from dry rock in the multiple sage triaxial test. Especially in undrained condition, at each stage consolidation process has to be carried out. Otherwise strength parameters are not obtained because of pore water pressure.

The mechanical behavior of the saturated soft rock in MST test has been investigated in detail. The lateral and axial strains, excess pore water pressure, volumetric strain and poisson's ratio were measured and the influences of these factors on the strength and deformability of rock were analysed.

(F-6)

(27) The Effects of Systematic Rock Bolts on the Reinforcement of Bedrock

Tsuchiya, T., Matsumoto, Y. and Kawasaki, K.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 96-100, 1980,

In order to recognize the effects of systematic rock bolts used for "New Austrian Tunnelling Method", some experiments have been performed.

The number of rock bolts, bearing plates and types of bedrock model as evaluated by cohesion and coefficient of internal friction have been chosen as factors for the experiments.

The results obtained in these experiments are summarized as follows.

(1) Reinforcement with rock bolts has no influences on the initial modulus of deformation. The difference between samples with and without reinforcement is clearly observed after yielding of samples and the ultimate load is increased remarkably by rock bolts.

(2) The increase of ultimate load and modulus of deformation after yielding are changed with the conditions related to the bearing plates.

(3) It is possible to estimate the effect of reinforcement on the ultimate load by triaxial compression test where rock bolts are simulated as confined pressure.

(F-6, H-5)

(28) The Relaxation of Tertiary Sedimentary Rock - Seismic Behavior of Izumi Formation -

Hata, S., Tanimoto, C., Nishihara, A., Kariya, K. and Kishida, Y.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 106-110, 1980,

In the excavation of rock mass including many discontinuities such as Izumi Formation, Tertiary alternative layers of sandstone and shale which are heavily fissured in most of cases, the relaxation at discontinuities is considered to influence much to in situ strength characteristics.

Authors had the chance to carry out some field measurements at the construction sites of cut slope for a highway and vertical shaft for the foundation of a suspension bridge which were located closely in the same Izumi Formation. In the both of cases, seismic method was applied for the reasons that it has the outstanding advantages of being relatively cheap and rapid to apply, influencing large volumes of rock and being well experienced in Japan.

The propagating behavior of seismic wave through the rock mass with discontinuities is subjected to the state of 'stresses' , 'fracture frequency' (n) defined by the number of joints per 1 meter and 'velocity ratio' (k) defined by the ratio of primary wave velocity in situ (or through a cracked model) to that of intact rock (without discontinuity).

The results from the field measurement at the cut slope in which all stresses near the surface were relieved show that the reduction of k-value are nearly zero for B-class rock and 50 - 70 % for C-class rock. Also, the results from the one around the circular vertical shaft, of 3.6 m in dia. and of 20 m deep around which confining pressure acted in tangential direction, show less reduction such as 5 - 8 % and 3 - 5 % to for B-class rock and C-calss rock respectively.

Comparing with Ikeda's equation in the form of $n = 5.0 / k^2 - 4.0$, being based on the results obtained at more than 100 sites, the former case indicates very low k-value and the latter does rather high one under the condition of no variation in fracture frequency, the fact of that was confirmed by visual observation at the both sites.

In the laboratory test using piled specimens, having the dimensions of 4 cm and 10 cm long with 76 mm in dia., sampled from the same sites where the field measurements were carried out, the relations between the directions of loadind - propagating, fracture frequency - velocity ratio with some variation of gap in the range of 0.1 mm - 1.35 mm, and stress level - velocity ratio were clarified experimentally.

The following are concluded:

(1) The change of compression in the lateral direction to wave propagation has little influence to velocity ratio.
(2) The remarkable decrease of velocity ratio are recognized in the range of 50 to 0 kg/cm^2 at unloading and it reaches at the half of an initial value when the direction of wave propagation agrees with that of compression.
(3) The variation of velocity ratio is also subjected the interval of gap and lying material at joints.
(4) The excavation of the vertical shaft by the boring machine with a large diameter did not have any influence to the stability of the shaft, and it was confirmed that no interference by the excavation of an adjacent shaft 4.4 m far happened.

(F-2)

(29) An Overview on Geotechnical Problems of Soft Rocks with Special Reference to Mudstone

Nakano, R.

Tsuchi-to-Kiso, JSSMFE, Vol. 28, No. 7, pp. 1-10, 1980,

Fundamental geotechnical properties of soft mudstones are discussed in relation with the classification of mudstones for engineering purposes. Taking advantage of the swelling property of disturbed mudstone and the concept of critical state soil mechanics, the mechanism of landslides of Tertiary type is discussed.

It is also shown that the natural water content of softened clay sampled from a faulted zone in a face of Noshiro water tunnel driven through mudstone is in the range of critical state or fully softened state.

(F-5, F-6)

(30) Weathering of Granite and their Mechanical Properties

Miura, K.

Tsuchi-to-Kiso, JSSMFE, Vol. 28, No. 7, pp. 11-20, 1980,

The characteristic weathering of granite is the formation of granitic grus measuring tens of meters thick. The weathering process that goes on in granitic rocks is mainly chemical weathering by water (atomospheric input) that move through the crack system concerning the crustal movement and mineral breakdown during weathering probably is initiated at the crack. The rock type of granitic rocks, grain size of rock-forming minerals and crack system within the rock are especially important factors in the chemical weathering related to the rate of weathering and plays a major role in the mechanical properties of weathered granite.

(F-2)

(31) Changes in Hardness due to Excavation of Weathered Granite

Nakai, K.

Tsuchi-to-Kiso, JSSMFE, Vol. 28, No. 7, pp. 67-74, 1980,

This describes mechanical properties of weathered granite around Mt. Takakura and Mt. Yoko-o wich are located in western part of the Rokko Range. Seismic survey of measuring the velocities of P-waves was conducted at natural slopes and cut ground, to obtain change in hardness of weathered granite with depth below ground surface. The influence of excavation on change in hardness was also investigated.

(F-8)

(32) Strength Criterion of Rocks

Yoshinaka, R. and Yamabe, Y.

Soils and Foundations, JSSMFE, Vol. 20, No. 4, pp. 113-126, 1980,

To investigate the strength characteristics of soft rocks, consolidated-drained triaxial compression tests were performed with mudstones, siltstones, tuff, weathered granite and so on. Maximum stress of applied confining pressure was about 30 MPa. Radial compression tests under confining pressure were also performed to study the mechanical properties under tensile stresses.

From these series of experiments, it may be concluded that the relationships between confining presssure and strength (maximum and residual) are generally non-linear.

These strength relations can be expressed as the following power function;

$$(\tau_m/\tau_{m0}) = \alpha(\sigma'_m/\sigma'_{m0})^{\beta}$$

where $\tau_m=(\sigma_1-\sigma_3)/2$, $\sigma'_m=(\sigma'_1+\sigma'_2+\sigma'_3)/3$, τ_{m0} and σ'_{m0} are at the case of $\sigma'_2=\sigma'_3=0$. α and β are material constants for rocks and $\sigma'_m>0$. The value of α is generally about unit and in the range of $0.96-1.23$ and β is in the range of $0.44-0.85$.

The normalization by $\tau_{m0}(=q_u/2)$ and σ'_{m0} $(=q_u/3)$ makes possible to represent with the same values of parameters α and β, the strength reduction due to scale effect and strength relation of sedimentary rocks which have the same geological history and of granites of various degrees of weathering which are distributed in the same petrographic province.

The applicability of proposed power function to the hard rocks and rock masses were investigated. Consequently, it is clarified that the proposed equation can be applied to the hard rocks which has the unconfined compressive strength of 20-200 MPa and also applied to the closely jointed rocks which can be regarded as the model of rock masses.

(F-6)

(33) Theoretical Studies on Cutting Force of Rock - Fracture Mechanism in Rock Cutting -

Nakajima, I. and Kinoshita, S.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 95, No. 1092, pp. 49-55, 1979,

In rock cutting, the chip-segment formation attributes to the open crack propagation which is brought about by the development of the yielding region adjacent to the cutting point as shown in Fig. 1.

In the present paper, the cutting mechanism was studied theoretically by applying a cantilever beam model to the formation of the chip-segment, and the formula to estimate the cutting force was derived as a function of the variables such as cutting depth, fracture toughness, rock properties of necessity and assumed angle of crack extension plane.

The formula was demonstrated to be good agreement over a wide range of cutting depth with the experimental results for AKIYOSHI marble if the value of the fracture toughness was taken as 0.1019 kg·cm/cm^2 and the angle of the crack extension plane as 25° which was obtained from the experiments. Consequently, a theoretical interpretation was given for the characteristics of cutting force versus cutting depth which had been pointed out in the previous studies on rock cutting.

(F-6)

(34) On the Model Rule of the Mechanics of Rock Cutting

Nishimatsu, Y., Akiyama, M. and Okubo, S.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 95, No. 1092, pp. 57-62, 1979,

Most of the laboratory rock cutting test postulate implicitly that the model rule is valid in the mechanics of rock cutting. In order to establish the validity of this often postulated, but not verified model rule, a series of laboratory rock cutting tests is conducted in the wide range of the depth of cut and width of blade.

Assuming the validity of model rule, the equation of rock cutting should maintain dimensional homogenity. Considering this theoretical requirement, a general form of the equation of cutting force is deduced, by means of dimensional analysis.

Based on the test result as well as the theoretical consideration, the equation of rock cutting is determined.

It is conclude that

(1) the equation of cutting force is expressed as

$$P = (a\frac{t}{B} + b) \cdot t \cdot B + c$$

which maintains dimensional homogenity;

(2) any equation satisfying the model rule is not determined for the thrust force;

(3) the cross-sectional area of excavated groove A is expressed as

$$A = (a\frac{t}{B} + 1) \cdot t \cdot B$$

which maintains dimensional homogenity;

where t is the depth of cut and B is the width of blade.

(F-6)

(35) Study of Rock Breaking by Micro Wave

Misawa, S.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 95, No. 1093, pp. 131-136, 1979,

An experiment to break or weaken rocks by micro wave was performed. The output power of the micro wave has 20 ~ 80kW with 915 MHz, which was applied in order to generate thermal stress in some kinds of rocks and concrete owing to temperature increase in the rocks according to the principle of "Dielectric Heating".

Then, the followings were obtained within this experiment.

1) The temperature increase is approximately in proportion to the output power.
2) The temperature increase is approximately in inverse proportion to the distance between aperture face of electric/magnetic horn and rock surface.
3) The temperature increase becomes higher as aperture area of micro wave horn is smaller in constant output power.
4) Main factor to crush the rock specimen by heating is to generate the thermal stress by rock heating.
5) The rock with higher water content tends to have higher temperature increase in same rock type.
6) The penetration depth of applied micro wave depends on dielectric constant and dielectric loss of the material.

(F-8)

(36) Characteristics of Blasting Vibrations and their Response Spectra

Ri, I., Sassa, K. and Ito, I.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 95, No. 1094, pp. 187-192, 1979,

In order to discuss the safe limits of blasting vibrations for residential structures, it is necessary to know the magnitude of structure's vibrations. But, it is a troublesome thing to measure the vibration of structure, comparing with the measurement of ground vibrations. Therefore, the response spectra which can be calculated from the measured ground vibrations become a useful information to discuss the effects of blasting vibrations on structures.

In this study, the vibrations produced by instantaneous, millisecond delay and two rows decisecond delay bench-cut blastings were measured both on the structure and on the ground near it. Then, the vibration data were analyzed and the response spectra for each blasting condition were calculated from the measured ground vibrations. As the results, the resonance frequency of most sensitive structures for blasting vibrations, and also the degree of excitation of structure's vibrations against ground ones were obtained.

(F-7)

(37) Measurement of the Ground Vibration Caused by Open Pit Blasting

Yamaguchi, U., Shimotani, T., Kubota, S. and Takeuchi, T.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 95, No. 1097, pp. 393-398, 1979,

Ground vibration caused by open pit blasting was measured.

To obtain accurate particle-velocities of ground vibration, some corrections, such as noise elimination, frequency equalization and so on, were necessarily required.

Experimental equations were deduced from the measurement which described the relations between maximum particle velocities of the vibration and some blasting conditions, namely, amount of the charge, distance from the blast, direction of the blasting, and the ignition method.

(F-7)

(38) Theoretical Investigation of Gas Pressure Distribution around a Borehole and Flow Rate

Goto, K., Itoi, R. and Uchino, K.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 95, No. 1097, pp. 399-404, 1979,

Solutions of the gas flow equation are of particular importance in gas control in coal mines. From this point of view the authors carried out the calculations of pressure distribution around a borehole and gas flow rate into the hole, using the implicit form of the finite difference equation. Also, as an application of the results of the calculation a method is proposed for measuring apparent permeability of coal seam in situ.

(F-2)

(39) The Study of the Stress Distribution and the Strain Measurement on Crystalline Rock Specimens, - In the Case of Marble -

Shimotani, T., Yamaguchi, U. and Yamatomi, J.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 95, No. 1098, pp. 455-460, 1979,

In many cases, rocks are composed of many crystal grains, and the stress distribution under uniform external force is not homogeneous but rather heterogeneous. This heterogenity is caused by the difference of elastic constants of each crystal grain. On the other hand, to measure the elastic constants of crystalline aggregate as a whole, it is necessary to eliminate the influence of individual grain properties. Therefore, the length of the strain gage must be considered carefully for the measurement. In this study, elastic constants of marble are measured, varying the gage length, and then, FEM analyses of uniaxial compression of marble composed of calcite are carried out. The results are follows;

1. Tensile stress greater than or equal to the 0.5 times as large as the axial compression stress is induced in the cross sectional plane of the specimen.
2. This tensile stress may elongate pre-existing cracks or nucleate new cracks.
3. To measure the elastic constants of crystalline rock specimen, the volume of specimen must be greater than 500 times grain volume.
4. The length of strain gage must be longer than 10 times apparent grain size.

(F-3)

(40) Laboratory Measurements of Permeability of Soft Rock Ground, - Foundamental Studies on the Permeability Analysis for In-Place Leaching -

Fujimura, H., Kiyama, H. and Sugitsue, Y.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 95, No. 1100, pp. 715-720, 1979,

Some kinds of laboratory measurements of permeability were carried out for such soft rocks as the weathering granite and the unhardened conglomerate including large gravels in Ningyo-toge Uranium Mine.

First, the constant-head and the variable-head permeability tests were performed. In the tests the permeability of the matrix fraction of soft rock was remarked. Following the treatment of compacted soils, the effects of void ratio as well as soil structure of the compacted matrix on its permeability were examined by changing the compaction energy and the molding water content.

Secondly the infiltration test was performed and its validity was discussed. The results indicate that the infiltration test can be applicable to the determination of the permeability constant K of the model ground with wide range of $10^{-8} \sim 10^{-4}$ cm/sec.. Together with little restrictions of the sample size and the grain size as well as easiness of the test procedures, it was judged that the infiltration test are acceptable for practical use as a indoor permeability test of soft rock for in-place leaching.

Lastly a laboratory test of the suction withdrawing method which will be expected as a useful method of forced withdrawing the pregnant liquor at in-place leaching was conducted. The rate of progress of the wetting front in the ground and the foundamental relationships among the suction pressure, the withdrawing amount of water and the withdrawal zone around a suction pipe were clarified.

(F-4)

(41) Experimental Study on Air Drying of Coal Measure Rocks

Ichinose, M., Uchino, K. and Yanagimoto, T.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 95, No. 1101, pp. 797-802, 1979,

As an investigation of the mechanism of water movement in rocks related with the problem of moisture pick-up by ventilation air current, experiments of air drying of coal measure rocks were carried out and the characteristic curves of drying of the rocks were obtained.

The results are summarized as follows:

(1) When the initial water content is high, in other words, the porosity is large, the characteristic curves are similar to those of such porous materials as small particles. Namely, in the first stage, the constant-rate period is observed and then the falling-rate period appears with decreasing water content, and this falling-rate period is mostly divided into the first falling-rate and the second falling-rate.

(2) When the initial water content is less than about 0.07, only the falling-rate period appears irrespective of kinds of rocks. Then, the critical water content may be considered to be about 0.07 in the experimental condition.

(3) During the falling-rate period, the drying curves of sandstones are nearly linear, while those of shales are S-shape configurations. This indicates that shales are more difficult to dry than sandstones, and the same conclusion is obtained from comparison of equilibrium water contents of these rocks.

(F-8)

(42) Failure Stress Conditions of Brittle Materials

Ogino, S., Mizuta, Y. and Urano, Y.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 95, No. 1102, pp. 843-849, 1979,

Triaxial compression tests applying uniform confining pressure and biaxial compression tests of two types of rock and cement mortar were performed using a simplified compression apparatus which had been reformed by the authors in order to improve the performance for polyaxial compression tests.

The envelopes of failure stress circles obtained were similar in shape to hyperbolic curves.

On the other hand, the authors obtained the failure stress conditions mathematically, extending the Griffith's theory for failure in two dimensions to the brittle materials containing needle-shaped and penny-shaped cracks.

It was found that the general trend of experimental results agrees with that of calculated results on materials containing the needle-shaped cracks.

(F-6)

(43) Some Results and Consideration on Permeating Tests of Acidic Mine, - Studies on the Technique to Prevent the Pollution at Closed Mines (4) -

Yamaguchi, U., Takata, A., Fujii, N., Shimohashi, K., Nishida, Y. and Ohshio, A.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 95, No. 1102, pp. 851-856, 1979,

In order to solve pollution problems occurred by acidic mine water, concrete plugs or seals are considered effective to block water flow through roadways, seal ore body and improve the properties of mine water.

A kind of permeating tests, input method by pressurized acidic mine water, were applied to concrete blocks and cement mortar blocks. Pressurized water of 9 kg/cm^2 intruded into these samples of 30 cm length until a certain depth during 1 week to 2 years.

Relations between intrusion depth and test duration were examined theoretically and experimentally under the influences of physical properties of concrete, acidity and iron ion concentrate of water and so on. Complexity of the intrusion behavior caused by the complicated mechanism of wettability or permeability of dry concrete samples, was amplified by the reactions between cement and acid. In general, a static intrusion of acidic water is liable to be restrained physically by the occurrence of compound near concrete surface.

(F-4)

(44) Mechanical Characteristics of Cement Mortar at Low Temperature

Katsuyama, K., Kuriyagawa, M. and Kato, S.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1103, pp. 7-12, 1980,

With the rapid progress of the chemical industry and the result of coming energy crisis, there is a tendency to increase in usage of a wide range of energy resources and in the quantities. Most typical liquid fuels are liquefied natural gas (LNG). As a result, many diversified hazards associated with LNG are recognized. LNG will be stored in tanks made of concrete or in underground spaces. But there are many unknown points about behavior of concrete and rocks at low temperatures. Here, the authors studied mechanical characteristics of cement mortar in range of temperature from room temperature to $-180°C$.

Main results obtained are as follows:

1) The tensile strength of cement mortar becomes maximum at the temperature of about $-150°C$ and is 2.4 times as large as that at the room temperature. (See Fig. 3)
2) The maximum compressive strength is obtained at abovementioned temperature and is 2.2 times as large as that at the room temperature.
3) The maximum Young's modulus and Poisson's ratio are obtained at the temperature of about $-150°C$, and are 1.4 and 1.5 times larger than those observed at the room temperature respectively.
4) When samples are saturated with water, their maximum tensile and compressive strength are 4.5 times as large as values obtained at the room temperatures. And their Young's moduli become much larger.

(F-8)

(45) On the Failure and Displacement of Concrete Plug for Sealing in the Pit Mouth of Closed Mine (2nd Report), - Studies on the Technique to Prevent the Pollution at Closed Mine (5) -

Shimotani, T., Yamatomi, J., Nishimatsu, Y., Oka, Y., Nishida, Y. and Nakano, K.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1104, pp. 55-61, 1980,

The concrete plug must be strong enough to support the hydrostatic pressure of mine water to seal the pit mouth of abandoned mines. In previous report, the test result of model plugs which were installed in hard rock was reported, and suggested that the conical plug is strong enough to support the pressure. In this report, the result of elastic F.E.M. analysis using the elastic constants obtained in previous report is reported. Furthermore, test results of model plugs installed in soft rock are reported. In order to explain these test results, elasto-plastic F.E.M. analysis considering tensile crack are performed.

The results of analysis obtained are as follows;

1. A remarkable tensile stress concentration is generated at the corner part of the rear end face of the plug.
2. Caused by this stress concentration, tensile crack is initiated and propagates to the free surface of rock, forming a conical fracture surface.
3. In the case of permitting the pressurized fluid to intrude along this fracture surface (experimental condition of previous report), stress field varies extremely, and elastic analysis become no more adequate to explain the fracture of the plug.
4. In the case of inhibiting the intrusion (experimental condition of this report), the formation of conical fracture conspicuously reduces the supportability of rock to the pressure.
5. Thus, the plug must be designed to reduce this stress concentration.

One example of plug shape which can reduce stress concentration is also shown.

(F-6)

(46) Study on Thermal Fracturing of Granite by Using a Carbon Dioxide Laser

Hashimoto, B. and Murahara, M.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1104, pp. 63-70, 1980,

This paper shows the mechanism of fracture formation of a granite caused by thermal stress in the case of applying the impulsive CO_2 laser beam to its surface.

The equation for heat conduction in solid according with the conditions of the laser beam irradiation is solved, and the temperature distribution in the rock for each time elapsed is calculated by making use of its thermal properties in various temperature surroundings by employing the laser flush method.

Applying the temperature distribution to the common axi-symmetric finite element method, the thermal stresses in the rock can be obtained. In this process for setting up external forces of the nodal points the 'thermal' Young's modulus is used instead of conventional Young's modulus.

Appropriateness of above temperature calculation is confirmed experimentally by two ways. One is to observe the distribution of the surface temperature by infra-red ray TV camera, and the other is to measure the surface displacement perpendicular to it by He-Ne laser holography.

The simulation is made for the fracture propagation with time elapsed. The Griffith theory is adopted for the evaluation of fracturing in each element mesh in FEM.

In this simulation, it has become clear that the greater part of the fractured elements occurs at tensile stress region, and the fractured region caused only by the thermal stress is limited.

(F-8)

(47) The Effect of Loading Rate on the Behavior of Deformation and the Strength of Rocks

Sano, O., Nishimura, H., Terada, M. and Ito, I.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1105, pp. 141-147, 1980,

In the previous report, the authors discussed theoretically the relationships between the stress rate and the inelastic volumetric strain rate, and also the strength of rocks. Now we tried to improve the uniaxial compression testing arrangement, and then attempted to verify experimentally the equations in the previous report and to evaluate the several parameters.

Granodiorite was selected for this study because it is very compact and consists of alkali-silicate minerals. The specimen's configuration was circular cylinder whose length /diameter ratio was about 2.6 according to the suggestion by Mogi[3]. The platens used were slightly larger than the specimen in diameter to reduce the clamping effect. After the loading conditions were checked numerically and experimentally, specimens were subjected to the uniaxial compression at constant deformation rates at which the strength measurements are usually performed.

The results obtained are as follows:

(1) The clamping effect near the ends of the specimen is reduced and the uniform stress field extends remarkably under the loading condition used in this study.

(2) The inelastic volumetric strain rate, $\frac{d\varepsilon_{vi}}{dt}$, is expressed as a function of stress, σ, and stress rate, $\dot{\sigma}$, namely

$$\frac{d\varepsilon_{vi}}{dt} = A_4 \sigma^{2m-3\left(\frac{l-m}{l-1}\right)} \dot{\sigma}^{\frac{l-m}{l-1}}$$

An exception, however, exists in the region above 80 ~ 85% of the fracture strength, where the inelastic volumetric strain rate accelerates.

(3) The strength, σ_{max} , is related to the stress rate by

$$\log \sigma_{max} = \frac{1}{b+1} \log \dot{\sigma} + A_5$$

where A_4 and A_5 are constants.

(4) The indirect measurement developed in the previous report suggests that the parameters b and m are 32 ± 2 and 2.57 ± 0.06, respectively.

(F-6)

(48) Fracture Toughness of Rock in Splitting Test, - Size Effect of Tuff Specimens on Fracture Toughness -

Kobayashi, R., Matsuki, K. and Otsuka, N.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1107, pp. 313-318, 1980,

A method of determination of the fracture toughness of rocks has been studied in this paper. The fracture toughness is obtained by the splitting test under the stiff-load as shown in Fig. 3. The rock specimens in which have a slot as Fig. 2, are prepared in this test. The slot produces a stress concentration around the tip of slot when the splitting force is applied to the slot, and a crack occurs from the end of slot into the rock specimen as Fig. 4. The crack initiation and the process of crack propagation are studied by the measurement of splitting load and crack opening displacement, and the observation of crack propagation.

The main results obtained in this study are as follows;

1) When the splitting force which becomes increase gradually reaches to the tensile strength of rock, a fracture crack initiates and propagates into the rock specimen. From these tests, splitting load – crack opening displacement curves are obtained as Fig. 5. Further, the growth of fracture crack in the post failure region is controlled by the stiff-load as Fig. 4.
2) Values of stress intensity factor K_I are determined experimentally with the compliance method as Fig. 9. From this study, it becomes clear that the fracture crack propagates unstably when K_I exceeds the constant value, namely, the fracture toughness K_{IC}. From above, it is considered that K_{IC} is also the material constant of rock.
3) The splitting tests of rock specimens with different height, width, and thickness are undertaken in order to obtain the size effect on the fracture toughness. It is considered from these tests that the suitable size of tuff specimen used for the rock splitting test is 200mm x 150mm x 20mm as shown in Fig. 10, Fig. 12 and Fig. 13.

(F-6)

(49) In-Situ Tests Using Crack-Detector with Rotating Probes for Measuring Sonic Velocity, - Studies on Crack Distribution and Sonic Velocity Change in Rocks (2nd Report) -

Kobayashi, R. and Sugimoto, F.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1107, pp. 307-312, 1980,

It has become very important in estimating the strength, the permeability and the other properties of rock to detect the distribution, the direction and the width of cracks in rock.

A crack-detector which can obtain the crack distribution and the sonic velocity change in rock, as already stated in 1st report, had been developed in this study.

The in-situ tests using a crack-detector which improved the inadequate points of the old type crack-detector are described in this report. It is the characteristic of the new type crack-detector with rotating two probes as show in Fig. 1 that the time required for a round measurement of its crack-detector is saved than that of the old type crack-detector.

The results obtained from the basic and the applied research for the study of crack distribution and sonic velocity change in rock are as follows.

1) As basic research for this study, the measurements of crack distribution and sonic velocity change were made on the surface of concrete floor with cracks. The results obtained from the basic research are shown in Fig. 3. The maximum value of sonic velocity of concrete floor, as shown in Fig. 3, is nearly equal to that of the concrete specimen. It is also clear that the patterns of pulse waves differ in the condition of concrete floor, that is the intact parts, the parts with closed cracks and the parts with open cracks, as shown in Fig. 2.
2) At Yaguki mine, Fukushima prefecture, the crack distribution and the sonic velocity change of rock were measured by inserting the crack-detector in NX boreholes. From the measurements, it is seen that the maximum value of sonic velocity in Fig. 6 is nearly equal to the velocity of specimen which is collected from the rock. Considering that the amount of scatter of sonic velocity as shown in Fig. 6 is closely related to the properties of rock, the correlation between the coefficient of variation of sonic velocity and RQD (Rock Quality Designation) obtained from NX- boring core is investigated. It is recognized from Fig. 7 that the coefficient of variation has linear correlation with RQD.
3) The results of in-situ measurements at the underground of Shakanai mine, Akita prefecture, are similar to those at Yaguki mine, as shown in Fig. 10. But, the coefficient of variation of sonic velocity has not a correlation with RQD, because the rock situated in where in-situ measurements are performed has many fractures along the core axis.

(F-8)

(50) In-Situ Measurements of Permeability in an Uranium Ore Vein, - Fundamental Studies on The Permeability Analysis for In-Place Leaching (2nd Report) -

Fujimura, H., Kiyama, H. and Sugitsue, Y.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1108, pp. 373-378, 1980,

In-situ measurements of the permeability in such soft rock ground as an uranium ore vein of soft congromerate and its footwall of weathering granite at the Ningyo-toge Uranium Mine were carried out.

The permeability coefficient of the weathering granite ground was determined by an in-situ pumping test and the obtained value was $4 \times 10^{-4} \sim 5 \times 10^{-6}$ cm/sec, and it is in satisfactory agreement with the laboratory test results reported previously.

The in-place leaching tests to withdraw the pregnant solution by the suction pump were performed under some several conditions in a zone (8m x 15m x 3.5m) of the ore vein.

The results show that the withdrawing rate of pregnant solution is closely related to the viscocity of the solution, the suction pressure and the distribution of suction holes, and that most of the correlations among them can be explained by the concept of the effective withdrawal radius deduced by the laboratory tests.

(F-4)

(51) Study on the Strength Failure of Marble and Calcite of Marble under Compression (1st Report), - Mainly about Experimental Results -

Shimotani, T., Yamatomi, J. and Yamaguchi, U.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1108, pp. 379-384, 1980,

Uni-axial, bi-axial and confined compression tests were performed on Akiyoshi Marble. Specimens were unloaded on several stages of these experiments, and optical micro-scopic observations were performed about thin sections made from these specimens. On the other hand, uni-axial compressive test was also performed on calcite specimens.

Based on these experimental results, some considerations about strength failure of these materials were discussed and following conclusions were obtained.

1) The fracture behavior of calcite was anisotropic. In c-axis direction it behaved as brittle, on the other hand in a-axis direction it behaved as elasto-plastic. And, the strength failure and yielding point was about 1500 and 40 kg/cm^2 respectively.
2) The linearity at low stress level and non-linearity at high stress level of the stress-strain relation of marble could be explained by the mobilization of the hindered cleavage sliding of calcite grain due to micro-crackings surrounding the grain.
3) The extended Von Mises fracture criterion well explained experimental results qualitatively, but quantitatively insufficient.
4) The anisotropy of lateral strain under bi-axial compression could be explained by the directional development of cracking from pre-existent cracks.
5) The formation of ultimate failure plane did not correspond to the point of strength failure, but rather corresponded to the rapid stress drop after the strength failure.

(F-6)

(52) Study on the Strength Failure of Marble and Calcite under Compression (2nd Report), - Mainly about the Result of Elasto-Plastic Analysis -

Shimotani, T., Yamatomi, J. and Yamaguchi, U.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1109, pp. 443-448, 1980,

Elasto-plastic analysis (EPA) on uni-axial compression of marble was performed using the extended Von Mises yield criterion, based on the fracture behavior of calcite. Some conclusions were deduced by comparison of the result of EPA to the experimental result. These were follows:

1) The result of EPA relatively well agreed to the experimental stress-strain curve of marble. But it showed rapid stress drop after strength failure which could not generally observed in the experiment.
2) The strength failure of marble dominantly depended upon the behavior of calcite.
3) The mechanism of the formation of failure plane should be considered including the cracking mechanism which would associate with the sliding on fractured surface.
4) The strength failure point under multi-axial compression could be estimated by "plastic Poisson's ratio" obtained by EPA.
5) The parallel model constituted by calcite could well explain the mechanism of the strength failure of marble.

(F-6)

(53) Evaluation of Rock Strength by Longitudinal-Wave-Velocity Measurement from the Stochastic Point of View

Okubo, S. and Nishimatsu, Y.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1109, pp. 449-453, 1980,

A theoretical model of rock was proposed to predict the strength of rock by longitudinal-wave-velocity measurement. Rock was assumed to be made of a homogeneous, isotropic, linearly elastic material containing a large number of penny-shaped cracks. The effective compliance of rock that contains cracks was evaluated following the way proposed by Amos Nur. The longitudinal-wave-velocity can be uniquely correlated with the effective compliance. The tensile strength of the rock was also evaluated with the aid of the stochastic process theory and linear fracture mechanics. From the theoretical considerations, the authors developed the foundamental equations by which field velocity data can be interpreted to the tensile strength. The experiments were carried out to measure ultrasonic velocity and tensile strength in laboratory. The theoretical result compared favorably with the experimental data of two kinds of shale.

We also studied the compressive strength of rock based on the modified Griffith theory. The apparent coefficient of friction obtained from data of direct shear tests remains almost constant for the sample rock used. This result indicates that the linear correlation exists between compressive and tensile strengths, therefore the theoretical equations for tensile strength can be used to estimate compressive strength with little modification. The experimental result also showed fine coincidence with the theoretical results.

(F-6)

(54) Study on the Strength Failure of Marble under Polyaxial Compression, - Stress Analysis around the Flat Ellipsoidal Cracks Using Eigen Strain Method -

Shimotani, T., Yamatomi, J. and Yamaguchi, U.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1110, pp. 529-534, 1980,

It is generally considered that the strength failure of rock under compression is caused by the accumulation of micro-fractures. For the purpose of obtaining the amount of the accumulation, stress concentration factors around flat ellipsoidal cracks under various composition of external stress were calculated using eigen strain method. It was so considered that the micro-fracturing of the defenite percentage of all pre-existant cracks yielded the strength failure of rock specimens. This percentage was obtained by the comparison of the theory to the bi-axial experimental results, and following results were concluded.

1) This percentage is 50% in the case of marble.
2) In this instance, the crack, the short axis of which inclines 30° or 80° to the direction of uni-axial stress, is micro-fractured.
3) And in this instance, the brittleness is 13.2, and this value agrees roughly to the experimental results.
4) The theory agrees qualitatively to the experimental results under the poly-axial compression, and so on.

(F-6)

(55) Computer Simulation on the Time-Dependent Deformation and the Strength of Brittle Materials

Hashimoto, B. and Oka, T.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1111, 587-592, 1980,

It is well-known that brittle materials such as rocks show time-dependent deformation, and there are a lot of papers which deal with the creep phenomenon and mechanism of such materials. These time-dependent visco-elastic phenomena, however, have mainly been studied from a phenomenal standpoint. Some of them show the fact that the creep is caused by the existence and occurrence of micro-cracks and the extension of them from the experiments detecting the acoustic emission. Furthermore, it is well-known that the time-dependent deformation of brittle materials is closely related to fracturing.

The authors have tried to simulate the time-dependent deformations of brittle materials caused by extending numerous inner micro-cracks on the basis of linear fracture mechanics by applying the finite element method. The results of this simulation fairly resemble an actual behavior of hard rocks concerning their time-dependent deformation.

In conclusion, it has become clear that the tertiary creep of brittle materials to be connected with the rupture is due to rapid extension of inner cracks, and that the reason that the compressive strength of such materials is extremely greater than the tensile strength is mainly ascribed to the internal friction which acts so as to obstruct the extension of such cracks.

(F-6)

(56) Simulation Model of Failure Process of Rock and its Application to Delayed Failure

Nishimatsu, Y., Yamaguchi, T. and Okubo, S.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1111, pp. 593-598, 1980,

Rock can be regarded as a kind of composite material which contains a sufficient number of structural particles with different mechanical properties. Accordingly the rock specimen was divided into 304 triangular elements and the Finite Element Method was used to simulate the failure process. Each element of model rock corresponds to a high or low elastic constant particle. Supposing that the failure process of each element is expressed as a 2-stage, i.e. 1-step Poisson process, a computer simulation of failure and deformation under a constant uniaxial tensile load was carried out by means of the theory of stochastic process and F.E.M.

Although each element has a most simple form of probability of survival, the strain-time behavior calculated by this computer simulation shows a similar tendency to that obtained experimentally in primary, steady-state, and tertiary creeps.

The P-t diagram calculated, assuming that the model rock specimen is subjected to the eccentric load, shows good agreement to that experimentally obtained P-t diagram.

The P-t diagrams became concave to downward. This result can be explained as probability of survival being expressed by linear combination of two different 1-step-Poisson processes. However, it is apparent from this computer simulation that not only the above mentioned mechanism, but also some extraordinary distributions of stresses caused by inhomogeneity of rock specimen and an eccentric load make the P-t diagram concave to downward.

(F-6)

(57) Thermal Piercing Simulation, - An Attempt to Estimate Thermal Piercing Rate and Thermal Cutting Depth -

Shimada, S. and Hokao, Z.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1113, pp. 795-801, 1980,

Thermal fracturing is one of the effective method for drilling and cutting the hard crystalline rocks. As for the thermal piercing rate, many workers proposed the theoretical, empirical and experimental equations. But these equations were derived in neglecting many actual conditions relating to thermal fracture process.

Based on the measured thermal and kinematic characteristics of jet flame impinging onto the flat plane, the thermal piercing rate of INADA granite was calculated by simulation and this calculation coincided closely with the experimental results. In the simulation the following conditions were considered;

i) temperature-dependence of rock properties,
ii) residual temperature in the rocks,
iii) size distribution of debris.

By the same method of simulation estimating thermal piercing rate, the procedure for calculating the thermal cutting depth was considered. This study makes it possible to forecast thermal piercing and cutting rate, if the properties of the rocks are known.

(F-8)

(58) The Effect of Confining Pressure and Flow Rate upon the Hydraulic Fracturing, - Fracture Mechanics Consideration -

Ishijima, Y. and Kinoshita, S.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1113, pp. 803-808, 1980,

Fracture mechanics solutions for hydraulic fracturing under confining pressure σ^{∞} are studied. Elastic problem of two symmetric cracks emanating from a hole in a plate is solved by utilizing Nishitani's method, under the assumption that the pressure along the crack is induced due to the steady-flow intrusion of fluid into the crack.

Attension is payed on the precise analysis of the crack opening process of closed cracks prior to the crack propagation, by adopting step-by-step procedure. Results are given both for the behaviors of long cracks (hydraulic fractures) when re-pressurized and for the behaviors of short cracks (pre-existing cracks) in terms of fracture initiation.

These findings for long cracks are (see Figs. 3 through 5);

1) Crack opening begins when the injection pressure reaches to $2\sigma^{\infty}$. And the injection pressure achieves its maximum value in the process of crack opening, that is, larger pressure is required to open the crack than to extend it, under the relatively high confining pressure condition.
2) The injection pressure at the final stage of crack opening, as well as the pressure at the onset of crack growth, approaches to σ^{∞} as a crack length increases.

And for short cracks are;

3) Maximum injection pressure is always attained at the onset of unstable crack growth (see Fig. 6).
4) Fracture criterion curve, where the crack extension pressure is plotted as a function of the confining pressure, is obtained for five different flow rates. For infinitely large flow rate, the curve is given by the line of slope 2, while for null flow rate, by the line of slope 1. For moderate flow rates, bi-linear curves are obtained which lie in a range bounded by the two limiting lines (see Fig. 7).

(F-6)

(59) Development of Computer System for Monitoring Seismicity Induced by Underground Coal Mining

Goto, T., Isobe, T., Mori, N., Sato, K. and Nohara, H.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1113, pp. 815-820, 1980,

A seismic method is one of tools to survey the state of the strata, and it is effective in especial to monitor the unstable rock failure caused by the change of stress and strain energy. From this point of view the field investigation has been carried out using the seismic method over eight years at four coal mines in Hokkaido. The investigation confirmed that the seismic method might be useful to examine the state of rock failures around underground excavations even if the measuring system was composed of primitive devices and an analogue recorder. But on the other hand it was realized that prompt and precise analysis of a large number of seismic events might be impossible unless an analogue measuring system was replaced by a computer system.

In 1976 the computer system was installed, whose main part was occupied by a 32-K words mini-computer. After the development of softwares for processing and analysing seismic data the system has been applied to a field investigation. In the present paper the measuring system including softwares will be described in detail.

(F-8)

(60) Studies on Crushing of Rocks by a Single Toggle Jaw Crusher

Tokuda, S.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1113, pp. 827-832, 1980,

In this paper, the author described the crushing load F_H and the crushing coefficient k in the case that the rock is crushed.

The author presented the theoretical equation of the crushing load F_H by solving the mechanism of a single toggle jaw crusher.

The author carried out the crushing experiments of the cylindrical mortar blocks, the cylindrical concrete blocks and the various irregular rocks.

In these experiments, the author didn't only inquire the crushing load F_H of each sample, but also considered the relation between the crushing load F_H of each sample and the load p which was inquired by the inner stress equation of each sample.

The principal results are shown below;

(1) In the case of a regular mortar block as a cylindrical shape and a homogeneous material, $\frac{F_H}{N \cdot p} = k$ is closely akin to 1, where N is the number of the breaking sections.

The value of $\frac{F_H}{N \cdot p} = k$ is decided by the shape, the size and the material of the sample. p is generally found out by the radial compression intensity σ_x, the distance between two load points y, and the diameter d of the sample. In the case of using this crusher, if the diameter of each sample is only decided, y is usually obtained a constant value. So that, it seems that F_H is estimated by σ_x and d of the sample.

(2) In the case that the irregular rocks are crushed, the value of $\frac{F_H}{N \cdot p} = k$ is influenced by not only the sort, the shape, the size and the number of cracks of the rock, but also the rotary angle of the upper end at the movable jaw θ and the position at the teeth of the crusher touching the rock.

But in the range of this experiment, namely, when y of rock is in the range of from 90 mm to 150 mm, when θ of this crusher is in the range of from 250° to 300°, and when this crusher is put in motion at the 316 r.p.m, k generally shows the constant value as showing in Table 2.

So that, it seems that F_H is estimated by σ_x and k, of rocks.

(F-6)

(61) Experimental Study on Hydrofracturing Stress Measurements, - Hydrofracture under Confining Pressure up to 250 kg/cm2 -

Ishijima, Y., Kinoshita, S., Ito, Y. and Machida, K.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1114, pp. 871-877, 1980,

Laboratory experiments were conducted to examine the validity of the observation equations 1 through 6 in the hydrofracturing stress measurements. Three kinds of rock materials having properties as shown in Table 1 were tested using the apparatus as illustrated in Fig. 2, under the controlled pressurizing rates of 1.0 to 200 kg/cm^2 s for fluid injection, and under the various confining pressure up to 250 kg/cm^2. The results of this study may be summarized as follows:

1. The relationship between the breakdown pressure (P_c) and the confining pressure ($\sigma\infty$) of these materials was found to be linear as described by Eq. 1, at least in a range of low confining pressure levels (Figs. 7, 8, 9, 10 and 11). However, it was observed in the samples of mortar and plaster that the P_c- σ_θ curves were bent over a critical confining pressure (Figs. 8 and 9).
2. For permeable materials, it was recognized that the breakdown pressure was liable to be influenced by the flow rate of injection (Fig. 13).
3. Stable crack growth could be achieved, too, for the permeable materials, by means of repetition of the testing procedures which consist of first pressurizing to the maximum value then followed by shut-in of the injected fluid and/or by releasing fluid (Figs. 4 and 5). The results of these tests revealed that the breakdown pressures were decreasing and converged to the value defined by Eq. 4, with elapsed pumping cycles. This means that the borehole strength T_θ in Eq. 1 can be estimated from Eq. 6 (Fig. 10 and 11).
4. It seems reasonable to define the instantaneous shut-in pressure P'_s used in Eq. 5' as the one at which the pressure-time curve during the shut-in process becomes linear with a constant slope (Table 3).

(F-6)

(62) Fracture Toughness of Rocks at Confining Pressure

Kobayashi, R. and Otsuka, N.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1114, pp. 879-884, 1980,

In order to determine the fracture toughness of rocks at confining pressure, the splitting tests in a triaxial vessel are undertaken on four kinds of rocks, namely OGINO tuff, AKIYOSHI marble, KIMACHI sandstone and INADA granite.

The rock plates of 200mm x 150mm x 20mm which have a slot are prepared in this test. The slot produces a stress concentration around the tip of slot when the splitting force in the triaxial vessel is applied to the slot, and a crack occurs from the end of slot into the rock plate. The relationships among splitting load, crack opening displacement and crack length during the fracture process of rock plate are studied in this test, and the values of fracture toughness KIC of various rock specimens at confining pressure are determined with the compliance method.

The outline of this study is as follows:

(1) To measure a crack length of rock plate splitted in triaxial vessel, the silver conducting 7 grid lines are drawn on rock plate as shown in Fig. 3. The position of crack-tip propagating in rock plate is recorded on a pen-recorder when the silver conducting grid lines are broken by the crack.

(2) The splitting load-crack opening displacement curves of various rock specimens are obtained at atmospheric and confined pressure as shown in Fig. 4. From the figure, it is clear that the rising part of splitting load-crack opening displacement curves at atmospheric pressure is relatively linear, but as confining pressure increases, the rising part of these curves becomes non-linear and the splitting load increases.

(3) From the study of the effect of confining pressure on the fracture toughness, it becomes clear that the fracture toughness of rocks increases with increasing confining pressure. For instance, compared with the fracture toughness at confining pressure of 240kg/cm^2 and that at atmospheric pressure, an increasing rate of the fracture toughness of OGINO tuff is about 70%, AKIYOSHI marble about 50%, KIMACHI sandstone about 150% and INADA granite about 100%.

(F-6)

(63) Features of Coal Bursts in Miike Mine and Considerations about its Mechanical Factors, - Study on Coal Bursts (1st Report) -

Kimura, O., Sugawara, K. and Okamura, H.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1114, pp. 885-890, 1980,

The purpose of this study is to investigate the mechanism of coal burst and the effective methods for destressing and strata control in order to conquest the coal bursts. In this paper, we study on the actual features of coal bursts in Miike mine and the geological characteristics in the locations.

The coal bursts have occurred many times along the longwall face of a flat coal seam, 1.8m thick. But every one of them is located in the limited area shown in Fig. 1. We can classify them by the magnitudes of damages likely shown in Table 1 and 2. Up to the present, the coal bursts have occurred anywhere in the face, but severe in the rise part of face. This may be caused by the concentrated stress in the intersection of the pressured zone in front of the face and the abutment of old working.

The important geological preconditions are the very thick sandstone in the roof, lying directly on the seam without faults, and the floor sandstone which is 2 ~ 3m thick and under which there is a locally developed coal seam, 0.4m thick, and a stiff sandstone, 6m thick, they are shown in Fig. 10 ~ 12. Statistically we conclude that the occurrence of coal bursts in this area closely correlates with the thickness of floor sandstone. Under 2m thick, the floor only swells along the levels and over 3m thick, the hazard of coal burst is removed. Other geological factors which may play a part in assessing the hazard of coal burst is the local fluctuations in coal seam thickness.

(F-8)

(64) Strength of Rock Mass Estimated by Testing Method of Shearing Rocks between Two Parallel Boreholes

Kobayashi, R. and Sugimoto, F.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1115, pp. 7-12, 1981,

In this paper, it is described that the estimate of the strength of rock mass can be made by means of shearing rocks between two parallel NX-boreholes.

The outline of this study is as follows;

(1) To estimate the in-situ rock strength, a new borehole-type shear instrument as shown in Fig. 1 has been designed. In the in-situ test, two NX-boreholes are drilled to the side wall of underground opening, and these boreholes are parallel to each other with the distance of 20mm or 25mm. Then the shear instrument is inserted in one side of the two boreholes and the rocks between two parallel boreholes are punched by a shear-edge (20mm x 40mm) which is pressed by the oil pump. The shear strength of the rocks can be calculated from the applied shear load and the shearing area as shown in Fig. 5. The shear strength in this test is conveniently termed as "Shear strength index"

The preliminary tests in the laboratory were taken on the relatively homogeneous rock blocks, and from this tests, it will be clear that the relation between the shear strength index and the uniaxial compressive strength of the rock blocks gives essentially straight line as Fig. 7-A.

The experimental equation is as follows;

$$S_C = 3.14\, S_i$$

where S_C is the uniaxial compressive strength (kg/cm^2) and S_i is the shear strength index (kg/cm^2).

(2) The shear tests were taken at −220 mL crosscut of Shakanai mine, Akita prefecture. In this in-situ test, the shear strength indexes were obtained at 43 points in the rock mass, which was consisted of rhyolite with joints.

The compressive strength of rock mass can be estimated from the cumulative distribution function of the shear strength indexes with the parameter proposed by B. Kostak. From above proposal, the compressive strength of rock mass, in which the in-situ shear tests were taken, was estimated to be about 530 kg/cm^2.

(F-6)

(65) Study on Biaxial Tests of Rocks, - Mechanical Behaviours of Rock Plate Specimens under Combined Stresses of Compression-Compression and Compression-Tension -

Kobayashi, R. and Furuzumi, M.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1116, pp. 77-82, 1981,

In order to study the failure criterion of rocks under the combined stresses, the biaxial tests were undertaken on three kinds of rocks, namely OGINO tuff, KAWARAGO tuff and KIMACHI sandstone. For these tests, a biaxial testing machine using the rock plate specimen was designed as shown in Fig. 3 and Fig. 4.

The main results obtained in this study are summarized as follows;

1) The failure strength of rocks under the combined stresses of compression-compression changes with the intermediate principal stress as shown in Fig. 6. The maximum value of failure strength of KAWARAGO tuff in compression-compression test is about 1.4 times the uniaxial compressive strength, KIMACHI sandstone about 1.9 times and OGINO tuff about 1.3 times. The increase of failure strength of rocks in compression-compression test shows that the magnitude of the intermediate principal stress has a considerable influence on the magnitude of the fracture strength.
2) The failure limiting line of rocks in compression-tension test gives the curved line part and the straight line part. The curved line part shows the range which the failure strength of rocks decreases as the tensile stress increases, and the straight line part shows the range which the failure strength approaches gradually to the uniaxial tensile strength.

(F-6)

(66) Fracture of Marbles in the Flexural Test under Confining Pressure, - A Study of Rock Fracture in the Flexural Test under Confining Pressure (1st Report) -

Matuki, K., Kobayashi, R. and Yoshida, T.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1116, pp. 83-88, 1981,

Four-point bending tests were undertaken in a triaxial vessel for fine grained and coarse grained AKIYOSHI marbles to reveal the features of bending fracture under confining pressure.

Main results obtained in this study are as follows:

(1) When the confining pressure is sufficiently high, the fracture cracks are arrested and, accordingly, the fracture propagation becomes more stable than that under low confining pressure where the rupture takes place immediately after fracture initiation.
(2) The bending moment-outer fiber strain diagram of fine grained marble shows sudden drop of bending moment caused by fracture initiation (Fig. 4(a)). On the other hand, bending moment in coarse grained marble increases monotonously until rupture (Fig. 4(b)).
(3) The outer fiber bending stress at fracture initiation increases rapidly with the confining pressure for both fine grained and coarse grained marbles. This suggests that the conventional failure criterion can not predict the outer fiber bending stress at fracture initiation under confining pressure (Fig. 11(a) and (b)).
(4) Number of fracture cracks initiated between the two loading points increases as the confining pressure increases and decreases as the thickness of the specimen increases (Table 2). On the contrary, average ratio of the length of arrested fracture crack to the thickness of the specimen decreases as the confining pressure increases and also decreases as the thickness of the specimen increases (Table 3).

(F-6)

(67) The Analysis of the Fracture of Marble in the Flexural Test under Confining Pressure from the Viewpoint of Linear Fracture Mechanics, - A Study of Rock Fracture in the Flexural Test under Confining Pressure (2nd Report) -

Matsuki, K. and Kobayashi, R.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1117, pp. 161-166, 1981,

Fracture propagation in the flexural test under confining pressure is discussed theoretically from the viewpoint of linear fracture mechanics and compared with the experimental results on Akiyoshi marbles.

Taking the effect of pre-existing cracks into account, the differences in the test results between fine grained and coarse grained marbles with respect to the bending moment – outer fiber strain diagram and the stability of fracture propagation are explained by the stress intensity factor as a function of fracture crack length provided that the external forces are kept constant after fracture initiation (Fig. 8 (a) and (b)).

Fracture toughness and the effective length of pre-existing crack for fine and coarse grained marbles are evaluated from the relationship between the confining pressure and the outer fiber bending stress at fracture initiation. This is summarized in Table 1 which shows that the effective length of pre-existing crack is approximately 8 times grain size for fine grained marble and approximately 3 times for coarse grained marble, and that fracture toughness increases with the confining pressure, especially when the confining pressure is greater than 120 kg/cm^2.

Also, it is shown that the number of fracture cracks initiated between the two loading points is determined by the relaxation zone created by the initiation of fracture crack and, therefore, the number of fracture cracks depends directly on the average length of arrested fracture crack (Figs. 9 and 10).

(F-6)

(68) Solving Method of Permeable Flow by Means of Finite Element Method and Fourier Series

Oka, Y., Takimoto, M. and Danno, M.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1118, pp. 227-232, 1981,

In order to solve water pollution problems in abandoned mines, one of the authors has tried to analyze the behavior of ground water flowing through the underground in mine area based on the Darcy's flow in homogeneous media. This analysis has carried out on a certain model by using the finite element method. Although the analysis is applicably as long as the model is simple, there may be difficult to apply universally since the more the model is complex, the vaster the calculation becomes.

This paper deals with the solving method of that problem by using both the finite element method and Fourier series. By this method, analysis of the boundary value problems becomes easy and moreover the accuracy of the analysis is improved, and calculating time of a computer can be shortened.

(F-4)

(69) Unusual Pressures in the Coal Burst Area and the Effect of the De-Stress Drilling, - A Study on Coal Burst (4th Report) -

Sugawara, K. and Kimura, O.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1118, pp. 233-238, 1981,

First, the pre-mining pressures in the coal burst area of Miike mine are investigated by measuring the strains on the bottom surfaces of borehole, drilled in the roof, by the stress-relief technique. It is found that the vertical normal stress, equivalent to the weight of overburden, acts on the coal seam and both of the horizontal normal stresses are nearly equal to the half of the vertical normal stress. Secondary, the distribution of the pressure, induced by longwall mining, is examinated by the test drilling method developed in Germany. Analyzing the volume of drillings and the frequency of rock noise, reached our ears during the test drilling, as shown in Fig. 6, the existence of unusual additional pressure in the coal seam surrounding the mined area is concretely found out, and it is pointed out that this unusual pressure is ascribed to the behavior of the rigid hangingwall consisted of the thick sandstones.

The effect of the de-stress drilling is practically studied by examining the relation between the occurrence of coal burst and the record of the drilling. It is found that the hazard of coal burst at the longwall face can be removed by the effective parallel drilling, 100mm diameter, with the constant interval, 8m, of which the drillings is over 600 liters/m during the drilling in the high-pressure zone, 5 ~ 20m distant from the rise side entry, and the averaged frequency of the rock noise is caught over 2 times/m as shown in Fig. 7.

(F-8)

(70) Mechanical Properties of Rock at Cryogenic Temperature, - Fundamental Studies on Liquefied Natural Gas Storage in Rock Caverns (1st Report) -

Matsunaga, I., Kuriyagawa, M. and Kinoshita, N.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1120, pp. 431-436, 1981,

To store the large amount of liquefied natural gas (LNG), new methods of storing LNG in unlined rock caverns have been discussed in many countries. Thus, a systematic study has been undertaken to investigate the effects of cryogenic environments on the structure of rock cavern. In this study, mechanical properties of Emochi andesite and Sori granite, in both oven-dry and water saturated conditions, were investigated at temperatures from +20° to −180°C.

The following results were obtained.

1) Compressive and tensile strengths of dry specimens increased slightly with decreasing temperature, while those of saturated specimens increased rapidly.
2) Secant Young's modulus for saturated rocks tended to increase gradually down to −130°C and kept almost constant following further lowering of temperature. But that of dry rocks was not changed by temperature decrease.
3) Poisson's ratio of dry specimens did not vary much with the change of temperature, while that of saturated specimens was influenced by temperature.
4) It is estimated that dependence of these mechanical properties of rocks on temperature relates to the freezing phenomena of pore water.
5) Coefficient of thermal expansion and temperature range for expansion coefficient were given in Table 1.

(F-8)

(71) Size Distribution Characteristics of Fragments by Blasting, - Fundamental Study on Rock Blasting -

Otsuka, K., Miyakoshi, H., Sato, H., Sato, I. and Iwai, H.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1121, pp. 521-526, 1981,

Fixing our eyes upon the size distribution characteristics of fragments by blasting, we made experiments on crushing of uniform size cubic blocks which are made of cement mortar. The results obtained with the good reproducibility are as follows,

1) Rosin-Rammlar-Bennt diagrams of all blasting fragments were made of straight lines, so we admitted that the size distribution of fragments may be characterized by Rosin-Rammlar distribution function.
2) With constants which were found from lines for each fragment, namely the size distribution constant (n) and the absolute size constant (De), we calculated mean particle size (Dp) and specific surface area (Sw) through

$$\overline{Dp} = De\, \Gamma\left(\frac{1}{n} + 1\right)$$

$$S_w = \frac{\phi}{\rho_p} \cdot 10^4 \cdot \frac{1}{De}\left\{\Gamma\left(1-\frac{1}{n}\right) - \frac{0.0010\left(1-\frac{1}{n}\right)}{1-\left(\frac{1}{n}\right)}\right.$$

where ϕ = specific shape factor of crushing products which are given surface shape factor (ϕs) and volume shape factor (ϕv) through Heywood's method, ρ_p = density of crushed particles.

3) From optimum straight line through our experimental data, we found out following formulas,

a) The relation between the mean particle size and charge depth (W).

$$\overline{D_p} = 206 - 33.2 \cdot I_n W$$

b) The relation between the specific surface area ratio and charge depth one,

$$\frac{S_N}{S_{W_0}} = 4.72 e^{1.40\left(\frac{W}{W_0}\right)}$$

where S_{W_0} = specific surface area of original block, W_0 = max. charge depth, distance of center of block.

(F-8)

(72) On the Mechanical Behavior and Watertightness of Concrete Plug for Sealing the Abandoned Mine Roadway in Weak Rock, - Studies on the Technique to Prevent the Pollution at Closed Mines (7) -

Nishimatsu, Y., Oka, Y., Kojima, K., Shimotani, T., Yamatomi, J., Nishida, Y., Ochiishi, M. and Baba, A.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1123, pp. 917-922, 1981,

Model tests reported previously have shown a complicate behaviour of concrete plug and failure process of weak rock around the plug. They remain some technical problems which could not be revealed in the model test.

Thus, the in situ test is designed and conducted to reveal the problems remained, particularly the effect of fracture crack growth on the permeability of rock mass around the concrete plug.

The failure process is analysed by means of elasto-plastic F.E.M. analysis, and the predicted mechanical behaviour of plug as well as surrounding rock are compared with the test result.

It is indicated that the tension crack is generated in the rock mass near the corner of back face of concrete plug under a hydrostatic pressure of several kg/cm^2. This tension crack does not induce immediately total failure of rock mass, but remarkably increases the permeability of it.

Finally, a modified design of concrete plug has been suggested to prevent the occurence of tension crack and to keep watertight concrete plug.

(F-6)

(73) The Effect of Strain Rate on the Failure Process of Rocks in Compression

Nishimatsu, Y., Okubo, S., Yamaguchi, T. and Koizumi, S.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1125, pp. 1163-1168, 1981,

The uniaxial compression test of rock is conducted under various axial and circumferential strain rates with a closed loop servo-controlled stiff testing machine.

The stress-strain diagram under the constant rate of axial strain shows that:

(1) the deformation is purely elastic and does not depend upon the strain rate up to the immediate vicinity of strength failure point;

(2) the effect of axial strain rate on the failure stress is not remarkable and frequently covered up by the fluctuation between test pieces except Sanjome andesite.

The stress-strain diagram under the constant rate of circumferential strain shows that:

(1) Sanjome andesite is classified into so-called Class II defined by Wawersik;

(2) the failure stress under the constant rate of circumferential strain is smaller than those of axial strain, except Oya tuff;

(3) the stress-strain diagram in the post-failure region shows a remarkable fluctuation and the effect of strain rate is not detected.

(F-6)

(74) Seismicity Associated with Mining of Multiple Coal Seam, - Study of the Design of Mine Layout for Working Coal Seams Based on Rock Mechanics (1st Report) -

Isobe, T., Mori, N., Sato, K. and Goto, T.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1125, pp. 1169-1174, 1981,

The seismicity which was brought about by mining of multiple coal seam was measured at Sunagawa Coal Mine in Hokkaido over nine months in 1978. The magnitude distribution of seismic events was consistent with the Gutenberg-Richter's formula whose b-value was estimated as 1.3. The spatial rate of seismic energy associated with mining of the upper seam which was underwent at first was several times higher than the successive mining of the lower seams. On the other hand the spatial rate of energy released by mining of multiple seam was determined from the face element method. A numerical experiment showed that the ratio of the energy release rate at the upper seam to that of the lower seam had close agreement with the ratio of the seismic energy release rates that were measured. These results imply that the spatial rate of seismic energy induced by mining may be proportional to that of energy released from rock around underground excavations. On the basis of this observation mining sequence and mining method are discussed which can aid to prevent severe seismic event including rock burst.

(F-8)

(75) Some Laboratory Experiments and Interpretation of the Results on Hydrofracturing (1st Report), - Some Laboratory Hydrofracturing Experiments -

Ishijima, Y., Ito, Y. and Kinoshita, S.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1126, pp. 1235-1240, 1981,

Some laboratory hydrofracturing experiments under condition of controlled pressurization rate were conducted using three kinds of materials for two different borehole treatments of the specimen – one is jacketed with silicon rubber membrance at the hole surface (jacketed specimen) and the other is unjacketed (unjacketed specimen). In this work, the following results have been obtained.

1. Based on the statistical analyses, it has become clear that breakdown pressure Pc correlates well with confining pressure σ_∞ applied to the unjacketed specimen, and that concerning the regression line of $Pc - \sigma_\infty$, both the Pc value at 0 confining pressure and its slope increase in accordance with increasing pressurization rate. The data were further analyzed statistically to yield a trend that the value $dPc/d\sigma_\infty$ of fitting quadratic curve of $Pc - \sigma_\infty$ becomes slightly decreasing as the confining pressure σ_∞ increases (Table 1).
2. Weak correlation was found between the area of fluid penetration region around the hole and magnitude of breakdown pressure (equivalent to time of pressurization required for failure) (Fig. 1).
3. Two types of acoustic emission activity in time were distinguished. In unjacketed specimens, both two types were observed. On the contrary only one type was realized in jacketed specimens (Figs. 3, 4, 5).
4. Breakdown pressure of jacketed specimen was found to be fairly higher than that of unjacketed specimen, although such tendency was not recognized concerning the pressure at initial occurence of acoustic emission activity.
5. With an aid of scanning electron microscope, it was observed that growth of induced cracks occurs stably both in jacketed and unjacketed specimens during pressurization process preceding onset of failure (Figs. 6 through 9).

(F-8)

(76) On the Measurement of Anisotropic Elastic Constants of Rock-Like Materials by Uni-Axial Compression Test

Shimotani, T., Yamatomi, J. and Yamaguchi, U.

Journal of the Society of Materials Science, Japan, Vol. 28, No. 307, pp. 66-71, 1979,

In the field of rock mechanics, it is well recognized that the elastic anisotropy is one of the important mechanical properties of mineral, rock, and rock mass. But, because of troublesomeness of the measurement, anisotropic elastic constants of these materials are not measured so frequently. Particularly the constants which give the relationship between shear stress and strain are rarely measured. The reason is that the preparation of torsion test pieces is relatively difficult, although the torsion test is usualy thought to be essential for obtaining these anisotropic constants.

In this paper, it is shown that the all 21 elastic constants can be calculated using the transformation law of the co-ordinate of elastic constants, from the test results of uni-axial compression in which the axes of test pieces are varied to the principal axes of anisotropy.

As an example, the experimental results and the calculated compliances of calcite (trigonal) are shown. The preciseness of the measurement is also discussed.

(F-0)

(77) Experimental Study on Consolidation Properties of Peat

Akai, K., Ohnishi, Y. and Yasukawa, I.

Journal of the Society of Materials Science, Japan, Vol. 28, No. 311, pp. 89-95, 1979,

Structures such as a road constructed on peat continue to settle in many years and often produce serious differential settlements.

The mechanical properties of peat have been studied by many researchers, and the secondary compression is known to be predominant in the settlement. The prediction of settlement at the field based on the Terzaghi's consolidation theory has not been successful yet in many cases for peat.

This paper describes an experimental study to find out a more accurate method for predicting the field settlement. The results show that the consolidation settlement should be interpreted by strain, and the strain increase at the field seems proportional to the value determined in the laboratory by adopting the square law of the depth of the soil layer. Also the long-term settlement appears to be estimated from the laboratory test results by using the concept of Bjerrum.

(F-5)

(78) Finite Element Failure Analysis of Concrete Specimens in Uniaxial Compression

Nakagawa, K.

Journal of the Society of Materials Science, Japan, Vol. 28, No. 313, pp. 54-60, 1979,

The purpose of this study is to obtain the relationship between the internal failure mechanism and the whole deformational property of concrete specimens in uni-axial compression. As one of the methods to obtain such relationship, a numerical simulation analysis seems to be effective. In the present study, the finite element method was employed and a concrete specimen was divided into finite elements. Each finite element represents one of the failure patterns when its stress condition was satisfied in the element. The accumulated behavior of finite elements under increasing loading was discussed.

The macroscopic numerical result showed good simulation of the behavior of concrete specimens. It gave valuable informations about the effects of material constants on the stress-strain relationship of concrete specimens. (F-6)

(79) Mechanical Characteristics of Rocks Related to Cooling

Inada, Y. and Yagi, N.

Journal of the Society of Materials Science, Japan, Vol. 28, No. 313, pp. 61-67, 1979,

One of the problems of underground storage of L. N. G. is a rock stability at low temperature or after having been at low temperature.

In this study, the physical and the mechanical properties of rocks which had been at low temperatures of 0, −40, −80, −120, and −160°C were investigated. The physical and mechanical tests were carried out at room temperature.

The main results obtained are as follows :

(1) Both the compressive and the tensile strength of these rocks are smaller than those which had not been at low temperatures.

(2) The microscopic observation revealed an increase of microcracks in Granite with decreasing temperature, as indicated by the test results of Young's modulus and Poisson's ratio.

(3) The results of the X-ray diffraction show that cracks seem to grow at the interface between Quartz and Biotite, or between Quartz and Albite in Granite and Andesite.

(4) The coefficient of thermal expansion changes with cooling temperature. (F-8)

(80) On the Probability Distribution of Failure Life of Rock under Constant Tensile Stress

Nishimatsu, Y. and Yamaguchi, T.

Journal of the Society of Materials Science, Japan, Vol. 29, No. 317, pp. 86-91, 1980,

The failure lives of rock were observed under constant uniaxial tensile stress, and the results were analyzed on the assumption that the failure process of rock is a stochastic process. When the logarithms of probability of survival were plotted against the failure lives, a curve opening upwards was obtained on P-t diagram. This upwards concave curve on P-t diagram means that the failure process is neither serial nor cumulative, but consists of parallel Poisson's processes of 1st order.

It is suggested that this upwards concave curve is caused from the stochastic dispersion of the rate constant of failure by various factors, rather than the coexistence of a few parallel failure processes with definitely differen trate constants of failure. The experimental errors such as the deviation of loading axis, fluctuation of humidity, *etc.*, and the dispersion of a few macroscopic pre-existing cracks are suggested as the important factors among those affecting failure.

Based on the test results., the probability distribution of the rate constant of failure was graphically analysed, and expressed as a discrete distribution of four rate constants.

On the assumption that the failure process under constant load is not different from that under constant rate of stress, the fluctuation of uniaxial tensile strength of rock was estimated from the probability distribution of failure lives of the same rock under constant tensile stress. The estimated coefficient of variation of uniaxial tensile strength was not much different from the one obtained by the uniaxial tension test. (F-6)

(81) Effect of Strain Rate on Strength in Uniaxial Compression Test of Rocks

Nishimatsu, Y., Yamaguchi, T. and Okubo, S.

Journal of the Society of Materials Science, Japan, Vol. 29, No. 324, pp. 73-78, 1980,

In uniaxial compression tests of rocks, the quasi-static strength has a tendency to increase with increasing strain rate. In order to study this effect of strain rate on strength, a computer model of failure process of rocks was developed with Finite Element Method (F.E.M.) from the view point of stochastic process. In this computer model, inhomogeneity of rock specimens can be easily taken into account by changing elastic constants for each element.

The failure of each element in this model was taken to be the elementary process of macroscopic failure, and the failure process of each element was assumed to be a 3-stage *i.e.* 2-step Poisson process. By noting that the rate constant of failure for each element is a function of the stress level, the extended concept of stress severity was introduced to express the relation between the stress level and the rate constant of failure.

Although this computer model is based on the most simple assumption, the calculated results represented well the strain rate dependence of rock behavior in uniaxial compression, such as the effect of strain rate on strength and the stress-strain curve. This conclusion was well confirmed experimentally. (F-6)

(82) Mechanical Characteristics of Rocks at Low Temperatures

Inada, Y. and Yagi, N.

Journal of the Society of Materials Science, Japan, Vol. 29, No. 327, pp. 67-73, 1980,

In the case of underground storage of L.N.G., it is important to know the mechanical characteristics of rocks at low temperatures.

In this study, the physical and the mechanical properties of dry and wet rocks were investigated at low temperatures. An easy method of estimating the strength of rock at low temperature based on the Protod'yakonov's method were examined.

From the results of microscopic observation of mineral texture in rocks after low temperature treatment, the strength characteristics of rocks at low temperatures were explained. (F-8)

(83) Thermal Properties of Rocks at Low Temperatures

Inada, Y. and Yagi, N.

Journal of the Society of Materials Science, Japan, Vol. 29, No. 327, pp. 74-79, 1980,

Thermal diffusivity, the coefficient of thermal expansion and the velocity of ultrasonic waves which are necessary for calculation of thermal distribution and thermal stresses in a rock, were measured at low temperatures. Granite and Andesite were used as the rock samples. The measuring method of thermal diffusivity was developed in accordance with the application of Schmidt's theory.

The main results obtained are as follows:

(1) The thermal diffusivity of the wet rock specimens which have been submerged in water increased with lowering temperature, while that of the air dry specimens was nearly constant.

(2) The tangential coefficient of thermal expansion of the rocks decreased with lowering temperature.

(3) The dynamic Young's modulus calculated from the velocities of longitudinal and shear waves increased with lowering temperature. (F-8)

(84) Earthquake Prediction and Rock Mechanics - Review -

Mogi, K.

Journal of the Society of Materials Science, Japan, Vol. 30, No. 329, pp. 1-14, 1981,

Recent studies on earthquake prediction are reviewed from the standpoint of rock mechanics. On earthquake prediction, there are two extremely different opinions, that is, pessimism and optimism. Both such extreme opinions cannot be acceptable. On the basis of field observation data and laboratory experiments on fractures and stick-slips, it is discussed that earthquakes in some regions may be predicted by careful observations of precursory phenomena. Laboratory experiments suggest the followings: (1) Various kinds of precursory phenomena may occur prior to a sudden slip of the earthquake fault. (2) The degree of appearance of precursory phenomena may be greatly dependent on the mechanical or physical characteristics (c.f. heterogeneity) of the earthquake fault. (3) Precursory phenomena may be stable in the successive occurrence of earthquakes in the same earthquake fault.

In Japan, the first 5-year earthquake project was started in 1965. Now, the fourth 5-year project (1979-1983) is in progress. This research includes geodetic, seismic, geomagnetic, geoelectric, and geochemical observations; continuous observations of crustal deformation by strain and tilt meters; and gravimetric surveys. Detailed surveys of active faults and laboratory experiments on rock failure have also been conducted.

On the basis of the recurrence time of historical large earthquakes along the Nankai trough and the crustal deformation observed by geodetic surveys, the Tokai region, central Japan, has been indicated as a potential region for a great shallow earthquake of magnitude$\sim$8 since 1969. For the purpose of predicting this potentially large earthquake, a dense network of observation instruments has been set up in the Tokai region. The various data are telemetered to the center of the Japan Meteorological Agency (JMA) in Tokyo. When anomalous behaviour is noted, the Earthquake Prediction Council evaluates the data and conveys their findings to the director of JMA. On the basis of precursor data in this region, it is deduced that the possibility of the prediction of "the Tokai earthquake" may be high.

(F-0)

(85) Application of Generalized Rheological Model to Creep Behavior of Rock

Akagi, T.

Journal of the Society of Materials Science, Japan, Vol. 30, No. 336, pp. 48-54, 1981,

Creep tests were performed on Kobe layer tuff under seven uniaxial compressive stress states. It was found that the creep strain varied in proportion to stress up to the 50% point of unconfined compressive strength (σ_s), and that the creep Poisson's ratio did not vary with time at low stress levels. These results indicate that the time dependent behavior of ground structure consisting of this rock may be analyzed by the linear viscoelastic theory if the design stress is below $0.5\sigma_s$.

It is convenient to use a rheology model when the linear viscoelastic theory is applied. For this purpose, the evaluation technique of rheology model constants must be considered. In this paper, the generalized Voigt model was introduced and the determination method of its constants was discussed.

As the first step of this method, the approximate retardation spectrum was obtained by numerical differentiation of the experimental creep curve. Second, the number (n) of Voigt elements in the generalized Voigt model and the retardation times (T_i, $i=1, 2, \cdots\cdots, n$) were determined from the number of peak and the peak position in spectrum. Finally, the overall creep process was divided into several time ranges and the compliance J_i in each time range was determined by the method of least squares.

It was proved that the experimental results could be interpreted reasonably by the creep function determined by applying the present method.

(F-5)

G. [Analysis of Rock Engineering Problems]

(1) Image Output for Results from Finite Element Analyis

Murai, S. and Tateishi, R.

Journal of the Japan Society of Civil Engineers, Vol. 64, No. 6, pp. 38-43, 1979,

Massive data obtained from the finite element analysis will be effectively interpreted by giving their image outputs with colours or shades. The computer program developed for this purpose is presented.

(G-2, G-4)

(2) Application of the New Austrian Tunneling Method to Railway Construction

Yoshimura, H. and Watanabe, M.

Journal of the Japan Society of Civil Engineers, Vol. 64, No. 7, pp. 71-78, 1979,

The so-called new Austrian tunneling method, initiated in Austria and developed in European countries, has been attracting our attention for its various advantages. The design and construction process of the Dai-Ichi Hiraishi Tunnel of the new Toh-Hoku trunk line, to which this method has been applied, will be reported.

(G-4, H-5, K-11)

(3) Stress Change of Existing Tunnel Linings due to Parallel Tunnel Excavation

Ito, T. and Hisatake, M.

Proceedings of the Japan Society of Civil Engineers, No. 308, pp. 79-86, 1981,

Stresses in existing tunnel linings caused by new tunnel excavation in the elastic and the viscoelastic ground are analyzed by a coupling method of a finite element method and a boundary element method, by which boundary conditions at infinity can be satisfied. In the analysis, procedure of excavation and lining construction is taken into account. The accuracy of the coupling method and lining stresses obtained are confirmed, respectively, through elastic theory and by model tests with clays.

Made clear are the effects of the ratio of elastic constants of the ground and the lining, distance between tunnel centers, initial stresses in the ground, difference of tunnel diameters, and time dependency of the viscoelastic ground on the stress distribution of the existing tunnel linings.

Relations between the maximum stress of the existing tunnel linings and change of its inner diameter are also analyzed and shown in a figure. Using this relations, therefore, safety of the existing linings may be kept by measuring its diameter during and after new tunnel construction.

(G-4, H-5)

(4) Some Considerations on the Mechanism of Smooth-Blasting

Nakagawa, K., Sakamoto, T. and Yamamoto, K.

Proceedings of the Japan Society of Civil Engineers, No. 316, pp. 77-86, 1981,

Smooth blasting techniques are used for minimize overbreak (or fracturing of rock) beyond the designed boundary of main excavation areas. This paper presents an approach to understand the smooth blasting mechanism through discussions on the proposed theories and experimental studies on model specimens.

Sometimes the smooth blasting mechanism is explained with the superposition of shock waves from adjacent blast holes. According to the theory, cylindrical waves from

adjacent blast holes meet between the two holes. The guide hole effect in smooth blasting is explained by Ito and Sassa. One of the leading theories of smooth blasting mechanism is the explosion gas theory.

The writers explained one of the smooth blasting mechanisms through the crack propagation within a stress field. When a blast hole is detonated, the shock wave propagates away and several radial cracks initiate and propagate radially from the hole. For a little while after the detonation, gas pressure acting in th blast hole gives a stress field. With some time interval after the detonation of the first hole, the second hole is detonated and the cracks from the second hole initiate radially. The stress field due to the gas pressure of the first hole favors a few cracks between two adjacent blast holes.

In order to show this time interval dependence on smooth blasting effect, the writers conducted some series of experiments. The results were well explained with one or a combination of two of above mentioned smooth blasting mechnisms.

(G-4, K-4)

(5) On the Fluctuation of Water Ion Contents due to Civil-Geological Environment of Tunnel Seepage

Miki, K. and Yoshizawa, H.

Proceedings of the Japan Society of Civil Engineers, No. 282, pp. 31-43, 1979,

On the stage of under-construction of New-Aoyama tunnel in Mie Pref, Japan, a geological investigation of the tunnel seepage was performed, and the discrimination of two kinds of seepage, having remarkably different ion contents, was reported by writers in this Proc, JSCE, Sept. 1977; the one is pocket water in rock-crevice, and the other is run-through water in breccia zone. It was considered that, the disolved ions in the run-through water are tainted not so easy by the clays contemporaneously produced due to the water-rock interaction owing to comparatively speady flow, on the other hand, in the pocket water, the ionic exchange reaction is so easy to act.

In this paper, with regard to the chemical component of sample, the writers performed the Multivariate Analysis on the purpose of picking up the factors caused of the numerical discrimination of seepage. From mutual specific values, matrics of correlation coeff. and figures of regression curve were obtained through all seepages. Judging from these examinations, it is proved that the existance of two kinds of water is due to the difference of the dissolving mechanism, containing ionic reaction. Nextly, these factors of the differentiation of seepage are acquired as numerical values by Principal Component, and Factor Analysis. Moreover, it is cleared that the sample, collecting at random, can be clasified by Cluster Analysis deu to similality of factor.

In preparing this presentation, the writers would like to express their sincere gratitude to Dr Turumaki, Municipal Univ. Osaka, and Dr Nakai, Vice President T. Hamada, M. Kanamori of Kinki Nippon Railway Co. At the end we wish to thank Prof Murota, Dept of Civil Eng., Osaka Univ., for his advice and assistance during the final reading of the manuscript.

(G-5, H-5)

(6) Coupled Stress-Flow Finite Element Analysis of Soil

Ohnishi, Y. and Murakami, T.

Proceedings of the Japan Society of Civil Engineers, No. 298, pp. 87-96, 1980,

The influence of seepage on geotechnical engineering, such as dam, rock foundation, slope, etc., is so apparent that it is of vital importance to investigate the behavior of seepage in these field.

The conventional analysis of water through geologic materials has been done by graphical techniques or mathematical analysis. Recently the numerical methods were introduced, but most of the analyses were done without considering the stress flow coupling effect- i.e. a porous medium is assumed to be rigid.

In this paper, the coupled stress-flow finite element analysis including saturated - unsaturated flow has been presented. The coupling effect was first recognized by Terzaghi as consolidation. His theory was extended by Biot. Biot theory was reconstructed to fit the flow problem with free surfaces.

The difference between the concept of the new technique and conventional consolidation theory was briefly discussed with respect to the parameters of excess water pressure and hydraulic potential. The governing equation consists of two partial differential equations, in which the displacement and pressure head are unknown parameters. This equation is formulated by a finite element method with Galerkin's process.

Several examples are presented in the problems of slope stability with water flow, earth dam deformation in water filling. Excellent results have been obtained since the behavior of water and deformation or stress distribution of geotechnical structures are analysed simultaneously without any complexity. Of course, it is proved that the proposed method can be used to solved the conventional consolidation problem in soil mechanics.

(G-2, G-3, G-5)

(7) Study on Seepage Flow Through Rock Mass Surrounding Caverns for Petroleum Storage

Komada, H., Nakagawa, K., Kitahara, Y. and Hayashi, M.

Proceedings of the Japan Society of Civil Engineers, No. 300, pp. 69-80, 1980,

Liquid petroleum and petroleum gas can be stored in unlined underground rock caverns by making use of natural or artificial ground water pressure. In case of applying the unlined underground storage caverns to cracky rock mass it seems to be most important to study in advance the behaviour of the ground water through the rock mass surrounding the caverns.

This study, therefore, discusses the following subjects concerning to the unlined underground storage caverns:

(1) Numerical study on the effects of natural ground water pressure on the storage caverns.

(2) Numerical study on the effects of artificial ground water pressure on the storage caverns.

(3) Model experiment about gas leakage into the crack of rock mass.

The results are:

(1) According to the finite element analyses, in case of the caverns of heavy oil located 40 meters below natural ground water level in the rock mass with permeability of 1×10^{-6} cm/sec, the ground water surface fell down to less than 1/3 height of side wall of the caverns after about 20 years since the construction of the caverns. Moreover, in the rock pillar between the adjacent caverns, the surface of the ground water fell down to the level of the bottom of the caverns. Consequently, storage system using only natural groundwater pressure can not prevent the oil leakage into the rock.

(2) Assuming that the ground water with vertical hydraulic gradient $I_0 > 1$ should flow into caverns to prevent gas leakage, the caverns for crude oil and those for liquified petroleum gas are required to be located about 50 meters and 100 meters respectively below the ground water level. These depths may be varied in some degrees depending on the location of horizontal water injection boreholes.

(3) The hydraulic conditions necessary to prevent the gas leakage were investigated through the experiment with the acryl model of the rock mass. According to the investigation it is possible to design the storage caverns with smaller vertical hydraulic gradient than 1.0.

(G-4, G-5, H-5)

(8) Surface Settlement above the Conventionally Excavated Tunnels with Thin Earth Cover

Shimada, T.

Proceedings of the Japan Society of Civil Engineers, No. 296, pp. 97-109, 1980,

The ground surface settlement accompanying a lowering of the tunnel which was tested by using model experimental apparatus is approximated by normal distribution curve with the maximum value directly coming above the tunnel center.

The objective of the report is to consider the surface settlement of tunnel with thin earth cover and to arrange their countermeasures.

The amount of ground surface settlement is sharply reduced with an increase in earth cover. Furthermore, up to a certain amount of cover the ground directly above the tunnel makes a similar movement in the step of lowering the tunnel. It is thought that this cover has a certain kind of relation with cover capable of arching action. Therefore it may be assumed that the trend of reduction in settlement with an increased cover will differ according to the geological conditions. Considering the ground arching effect, the relation between the amount of lowering the tunnel and the earth cover is such that the former increases up to a certain amount of cover, after which it is practically constant irrespective of an increase in cover. From the various tests the author confirmed that the ground surface settlement becomes a maximum at a certain cover, with a trend of decreasing the cover either thinner or thicker than this.

Tests are performed at the Railway Technical Research Institute, Japanese National Railways, and the author wishes to express his gratitude to Mr. H. Oshima of the Chief R & D engineer for his efforts.

(G-4, H-5)

(9) Earthquake Observation around the Site of Underground Power Station

Komada, H. and Hayashi, M.

Proceedings of the Japan Society of Civil Engineers, No. 309, pp. 91-101, 1981,

Studies of underground site for large important structures are examined as basic means to effective use of national land. One of its feature is assumed that less input seismic motion at the earthquake-proof design is compared favorable with conventional on-ground site. However, detailed seismic records around large underground cavities are quite a few at present, so actual verification on above advantage by accumulation of these records are desirable. Therefore, seismic observations were examined at Shiroyama underground hydroelectric power station and the results were as follows.

(1) Observed earthquake
Date: From July 1976 until October 1978
Number of occurrence: 71 times
Typical earthquake:

1) Izu-Oshima-Kinkai earthquake (12:25, Jan. 14, 1978, M = 7.0)

2) Off Miyagi Pref. earthquake (17:16, Jun. 12, 1978, M = 7.4)

(2) Ratio of maximum acceleration at on-ground to that of underground (at 200m depth) is in the range of about 1/3 ∿ 1, but concentrating around 1/2. Hence

the acceleration at underground (at 200 m depth) is outlined to reduce about 1/2 those of on-ground.

(3) Increase of acceleration resulted by cavity excavation at the bottom of underground power plant is not apparent. Thus, location of input for aseismic analysis is no need to adopted deeper than the bottom underground cavity.

(4) Ratio of maximum horizontal acceleration to those of vertical acceleration at on-ground is in the range of about 1/2∿1, but no decrease of the value at underground is observed generally.

(5) At upper wall of the underground cavity, larger acceleration arose to short axis direction rather than to longitudinal of cavity.

(6) Investigation of phase correlation to the oscillation wave at main point of the underground cavity reveals that no positive correlation is observed at Izu-Oshima-Kinkai earthquake (distant earthquake), whereas positive correlation exist and appear as simple vibration mode at Off Miyagi Pref. earthquake (intermidiate earthquake).

(G-6, H-5)

(10) An Analysis of Excavation in Strain-Softening Rock Mass

Kawamoto, T. and Ishizuka, Y.

Proceedings of the Japan Society of Civil Engineers, No. 312, pp. 107-118, 1981,

Numerical analyses of rock structures by finite elements are classified into two types : a continuum rock mass is assumed with nonlinear constitutive laws including characteristics of discontinuities, and discrete joint elements are directly introduced for a model of discontinuity. In this paper the former type of numerical analysis is developed with the property of fracturing process including strain softening phenomenon.

The strain softening is idealized as follows:

1. Both the peak and the residual strengthes are determined by envelopes Mohr-Coulomb type.
2. Stress-strain curves of elastic, softening and flow regions are approximately represented by three segments of straight lines.
3. The stress changes with the minimum principal stress constant after peak strength.

An excavation of a large scale underground rock structure is numerically simulated in homogeneous rock mass with shotcrete lining. Furthermore a constructing process is simulated for the same model, which includes loosen region by the blasting.

Next the rock mass with a set of weak planes in one direction is assumed. The failure criterion proposed by Jaeger is governed by properties both of the matrix and of the weak planes. Such the rock mass is idealized as an anisotropically continuous material with following idealizations:

1. Each weak plane is independent on its geometry.
2. Macroscopically the rock mass is regarded as anisotropically homogeneous.

A rock slope excavation is simulated for that anisotropic rock mass.

(G-4, H-5)

(11) Verification of the Analytical Technique of Stability for the Soft Rock Foundation by the Numerical Simulation of the Field Test

Ito, H., Motojima, M., Hayashi, M., Kitahara, Y. and Hibino, S.

Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 21-25, 1979,

The purpose of this report, before analysis of stability about the mud stone foundation under actual scale of the power building, is to confirm following points by performing numerieal simulations of the shear test and bearing capacity test taken place at the field by means of non-linear numerical analysis;

(1) Propriety of the numerical method, evaluting values of and appropriating the non-linear numerical expression of material properties for the numerical analysis.

(2) The influence which the degree of scatter with regard to mechanical properties, in which is in practice to exist, exerts on bearing force of the mud stone foundation.

It is concluded as follows

(1) Based on the results of mechanical properties in the laboratory test for the sample of mud stone extracted from the field, the results of the numerical analysis simulated the shear test and the bearing capacity test taken place at the field coincide well with the results measured from the field tests.

(2) From the above-mentioned conclusion, the reliability of analytic method included numerical expressions of the non-linearty of deformation, anisotropic effect and etc. was confirmed. Further, the material values of mud stone being to use the practic scale of the analysis of stability were able to evalute and to determine.

(3) Because of the scatter of mechanical properties of rock foundation is avoided, in case that evalute the bearing force using the mean mechanical values as being usually performed, it is necessary that consider to discount the results obtained.

(G-3)

(12) Model Test and Numerical Analysis of Bearing Capacity of Soft Rocks

Yoshinaka, R. and Nishimaki, H.

Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 26-30, 1979,

The paper presents the bearing capacity and settlement behavior of rigid footing on soft rock with and without a virtical joint.

1. Two dimensional model bearing tests and numerical analysis:

Footing used in this experiment is 5 cm width and 15 cm length, and soft rock for foundation is tuffaceous sandstone with porosity about 42 %.

The mechanical properties of the rock were determined from triaxial compression test under consolidated drained condition. Size of rock foundation is 15cm×50cm×33cm, and the rock was rested in the rigid frame. Joint-plane was introduced by a diamond saw.

From experiment, following are obtained;

(a) Failure mode under a rigid footing is a punching shear type with a sharp wedge as shown in Photos. 1-3.

(b) Load-settlement relation depends on joint distance x/B, and changes from hardening to softening, as shown in Figs. 1, 2 and 4.

(c) Bearing capacity depends on x/B as shown in Fig. 3.

Numerical analysis was carried out by FEM. For calculation, the following conditions are considered;

(a) Strain softening from peak to residual stress.

(b) Non-linear stress-strain relation.

(c) Bi-linear Mohr-Coulomb failure criterion.

The results of calculations are shown in Fig. 5, and seems that this analysis is usefull to predict the bearing capacity and load-settlement behaviour of soft rock foundation.

2. Analysis of In-Situ plate loading tests:

Rocks as foundation in a test adit were highly weathered granite. Porosities of the rocks are about 27 % and 38 %. Diameters used for two loading tests are 30 cm and 40 cm. The mechanical properties of foundation rock for calculation were determined by consolidated drained triaxial compression test with undisturbed samples 10 cm dia, 20 cm length, and pressure meter test in borehole.

The results from experiments and numerical analysis by FEM are shown in Figs. 6 and 7.

(G-3)

(13) Tunnel Investigation Sustained Expansive Earth Pressure
Hayashi, K., Nishida, Y., Koga, Y. and Takasaki, H.
Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 51-55, 1979,

As the excavation of the tunnel was hampered by the expansive earth pressure, rockbolts were employed as a subsidiary method. The trial execution of the NATM (New Austrian Tunnelling Method), which combines the system rockbolts with shotcrete, was also carried out.

In this report, various ground behaviours under different work methods are compared and their characteristics are presented.

The geology of the tunnel site is alternated beds of sandstone and mudstone, and many fault shattered zone are exist. The P-wave velocity was 2.0 to 2.6 km/s and the earth covering was 20 to 40 meters. The compressive strength of rock was over 200 kg/cm^2 in most parts, but was partially below 10 kg/cm^2 in softening mudstone. The earth was subject to sudden softening and deterioration due to the change of stress and due to water.

The following results were obtained through our investigation:

(1) The ground behaviour is governed by the softening mudstone, though its quantity is small.

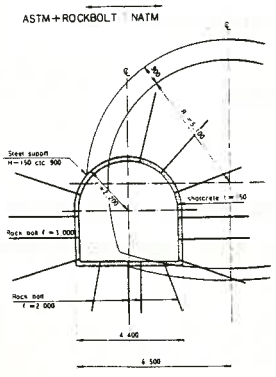
(2) The main cause of the expansive earth pressure is the plastic flow failure of the rock mass.

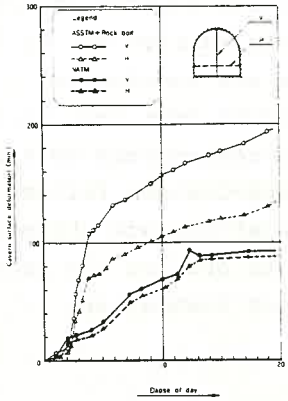
(3) The cavern surface deformation is caused largely by the progress of the facing, and the effect of the creep is small.

(4) The H-support, rockbolts and shotcrete were all effective, each supporting a portion of the ground force.

(5) The NATM is an effective method in this tunnel works since it is advantageous in respect of the following points:

a. Cavern surface deformation
b. Loosing zone
c. Interaction caused by the passage of the opposite heading
d. Stress redistribution





(G-0, H-5)

(14) Calculation of Support Resisting Forces for Pre-Dimensioning in NATM

Sakurai, T.

Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 56-60, 1979,

By means of seismic investgation in tunnel, the loosened area around opening is measured as the depth of lower velocity zone. On the other hand, elastic-plastic analysis using the rockmass strength, covering height and tunnel diameter in the investigatted site gives the radius of the plastic zone as the following equation.

$$\frac{R_c}{R} = \lambda^{\frac{1-\sin\phi}{2\sin\phi}}$$

$$\lambda = \frac{(P_o + C\cot\phi)(1 - \sin\phi)}{P_i + C\cot\phi}$$

,where R ; radius of tunnel
R_c ; radius of plastic zone
C ; cohesion
ϕ ; angle of internal friction
P_o ; average covering force
P_i ; inner force

Distinct relationship is found between λ (R=0) and measured loosened depth by seismic investigation, and the loosened depth becomes larger according to tunnel diameter.

The obtained result by seismic survey, which is generally excuted prior to tunnel construction along the tunnel route in Japan, is available to estimate the loosened depth by calculating λ. The estimated depth is also useful to design the length of rock bolt.

It is important to estimate the resisting force of tunnel support prior to construction. The supporting members consist of shotcrete lining, rock bolt and rockmass itself in NATM. In this report, a method to calculate the resisting force of rockmass using elastic-plastic analysis including the inner force P_i, which is estimated considering the supporting procedure, is also discussed.

(G-4, H-5)

(15) Evaluation of Rockbolting Effect in Tunnelling

Hata, S., Tanimoto, C. and Kimura, K.

Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 61-65, 1979,

It is known through experiences and studies in the past that the face has an important role as a temporary support. The rock mass near the face is stabilized by the half-dome action in the profile and the ring action in the cross section. When advancing the face, it is required to place the artifitial support to substitute for the half-dome action within the span length distance (D) from the face so as to mobilize the bearing capacity of the rock mass as fully as possible.

The so-called New Austrian Tunnelling Method (NATM), which 'rockbolting' and 'shotcrete lining' are applied adequately, is the latest and most feasible tunnelling method for this purpose. Both of the rockbolts and the shotcrete layer to be placed near the face are subjected to three dimensional stress field.

The main subject mentioned in this paper is how to design rockbolt system in consideration of the three dimentional stress field near the face and elasto-plactic behavior of the rock mass.

Some effects of fully bonded rockbolts placed systematically are 'mobilizing confining stress' and 'decreasing dilatancy'. From this view point, the procedure to design rock bolt system can be proposed by replacing the effects of rockbolting by the inner pressure acting onto the surface of the tunnel wall.

The contents of this paper are the following.

- The three dimensional stress field near the face and deformation of the circular tunnel having the radius 'a'
  (a = 5 meter for the numerical analysis)
- The elasto-plastic behavior of the bolted rock mass being subjected to 'Drucker's plasticity criterion'
- The relationship between plastic region W_1 and inner pressure p_i in the elasto-plastic rock mass being subjected to 'Mohr-coulomb yield criteria'
- The introduction of the 'strain softening behavior of the rock to the circular tunnel and the analysis of 'softening region' and 'flow region'
- The application to the expanding mudstone tunnel

The procedure proposed in this paper gives the answer to the problem in the rockbolting for the case of Naka-koku, one of the partitions of Nabetachiyama Tunnel (D = 10 m for the underground station) where the expanding mudstone has given big difficulty in tunnelling. When hydrostatic initial stress field (p_i), uniaxial compressive strength (q_u), angle of internal friction (ϕ_2) and the maximum allowance of plastic strain (ε_p) are considered to be 30 kg/cm^2, 10 kg/cm^2, 20 degree and 1.4 % respectively, it is obtained that the rockbolt system consisting of 18 fully bonded bolts (ø25, l= 9 m) per meter in the profile is required and the maximum allowance of the convergence is 30 cm.

(G-4, H-5)

(16) Experiment in Acting Mechanism of Rock Bolt

Hanaoka, S., Iwase, K. and Haruyama, S.

Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 66-70, 1979,

The reinforcement mechanism of a ended anchorge rock bolt has successfully been studied up to this time, and its field experience is enough. However, as to a fully bonded rock bolt, experimence is not enough and the reinforcement mechanism also is not distinct. The fully bonded rock bolt is apllicable for various tunnel grounds compared with the ended anchorage. Especially, it was reported to be effective for the swelling ground. I believe this report can give some information about the reinforcement mechanism of the fully bonded rock bolt.

The experiments we have done are.

1) One-dimensional compressive tests of which the test piece has some wires in it.
2) Two-dimensinol londing tests on gelatin model tunnel.

From results of these experiment it has been cleared that even if it set some wires in test piece, the strength have not increased much.

It is generally beleived that the rock bolt is not effective for the small inner friction angle material like gelatin. However, in this experiment the displacement could be decreased about 30%. I consider that it is because, not only the concentration of stress is decreased, but also compressive zone is formed. (G-4)

(17) Effect of Contact Clay on the Improvement of Stability along Contact Zone of Filldams

Matsui, I., Ikemi, M. and Okamoto, T.

Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 111-115, 1979,

The authors analysed stability of Takase dam, which was constructed by Tokyo Electric Power Company, by Finite Element Method. In this analysis, the authors applied the deformation characteristics obtained from measured displacement in the dam, and took into account of shearing displacement at the adjoining portion between core and foundation rock.

The purpose of this analysis was to evaluate stability of the dam from the distribution of stresses, and to evaluate the effect to resist some failure by seepage flow by setting contact clay along contact zone between core and foundation rock.

The results of this analysis showed that displacement in the whole part of the dam had fairly good coincidence with measured values of vertical crossarms, and that calculated shearing displacement along the contact zone seemed to follow real displacement.

From the above mentioned results, it became clear that shearing displacement improved the unbalanced stress distribution in the core zone near part of contact zone, and that such zone was kept watertightness by such improved stress distribution. So that it was concluded that contact clay was used effectively to keep stability of core.

Still more, material used for contact clay was conducted laboratory test using torsional shear and permeability test apparatus. And it was confirmed that there existed no bad influence to the permeability and shear resistance even if large shear strain occured in this material.

(G-2, H-4)

(18) Study on the Permeability Change of Rock Mass due to Underground Excavation

Motojima, I.

Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 121-125, 1979,

The permeability of rock masses arround the underground cavity for an electric power station are measured through the period of excavation.

The change of Permeability and its variation due to the excavation are discussed in this report.

(G-5)

(19) Study on Seepage Flow through Rock Mass Surrounding Caverns for Petroleum Storage

Komada, H., Nakagawa, K., Kitahara, Y. and Hayashi, M.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 31-35, 1980,

In unlined underground rock caverns, liquid petroleum and petroleum gas can be stored by making use of natural or artificial ground water pressure. In case of applying the unlined underground storage caverns to the cracky rock mass, it seems to be most important that the behaviour of the ground water through the rock mass surrounding the caverns is studied in advance.

This study, therefore, discusses the following subjects concerning unlined underground oil storage caverns.

1. The numerical study on the effects of natural ground water pressure on the storage caverns.

   In order to study the behaviour of natural ground water surrounding the caverns, two dimensional unsteady seepage flow analyses were performed by finite element methods.

   According to the finite element analyses, in case of the caverns for heavy oil located 40 meters below natural ground water level in the rock mass with permeability of 1×10^{-6} cm/sec, the ground water level fell down to less than 1/3 height of the side wall of the caverns after about 20 years since the construction of the caverns. Moreover, in the rock pillar between the adjacent caverns, the ground water level fell down to the level of the bottom of the caverns.

   Consequently, storage system using only natural ground water pressure can not prevent the oil leakage into the rock.

2. The numerical study on the effects of artificial ground water pressure on the storage caverns.

   In order to study the storage system using artificial water pressure from an array of boreholes for crude oil and liquified petroleum gas which are volatile and necessary to be stored in larger pressure than atmospheric pressure, two dimensional steady seepage flow analyses were carried out by finite element methods. The results show that the caverns for crude oil and those for liquified petroleum gas should be located about 50 meters and about 100 meters respectively below the ground water level. These depths may be varied in some degree depending on the location of horizontal water curtains.

   The allowable water leakage into the caverns should be determined by taking into consideration following factors; the mechanical stability of excavation, the cost of treatment of the water leakage and the cost for heating of stored fuel. The finite element analyses show that the amount of water leakage into a cavern would be 30 m^3/hr per stored oil of 1×10^5 m^3 in case of the rock mass with permeability of 1×10^{-5} cm/sec.

3. Model experiment about gas leakage into the crack of rock mass.

   The hydraulic conditions necessary to prevent the gas leakage were investigated through the experiment with the acryl model of the rock mass.

   According to the investigation it is possible to design the storage caverns with smaller vertical hydraulic gradient than 1.0 proposed by B. Aberg.

(G-5, H-5)

(20) Field Experiment Concerning Gas Flow in Rock

Tanaka, K., Ichikawa, Y., Makino, I. and Notohara, I.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 36-40, 1980,

In the safety assessment on the underground siting of nuclear power plant, it is necessary to know the transport behavior of gaseous fission products in the underground. The behavior can be basically expressed by a couple of equations with Darcy's and Fick's laws. At the present time, there are however a few field data which are applicable to determine parameters used in the equations.

The present paper describes on an outline of field experiment which, designed to obtain such data, was carried out in the underground siting of the pumped storage hydraulic power station.

A series of measurements has been done using test chamber excavated in Diorite, which has 2.5m in dia by 5m in length. The measurement system developed by EPDC for this experiment consists of gas sampling equipment using vacuum technique, mass spectrometer as helium detector and some conventional instruments.

The experimental results make it possible to determine such parameters to be used in the equations as air permeability, effective porosity and effective diffusion coefficients of gaseous fission products. Therefore, it becomes possible to assess actually the transport behavior of gaseous fission products in the underground, and also our developed system is said to be suitable to the field experiment of such purpose.

(G-5)

(21) A Fundamental Study on Underground Storage of Liquefied Natural Gas, - Temperature Distribution around Underground Openings -

Inada, Y. and Yagi, N.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 41-45, 1980,

In a design of underground openings for strage of L.N.G. whose temperature is -162°c, we must consider a mechanical and a thermal stresses.

A temperature distribution around openings is necessary for getting a thermal stress distribution.

This report presents the results of the theoretical analysis for temperature distribution around underground openings in various thermal conditions of openings surface. The finite devided rectangular and triangular elements method is adopted for the analysis.

Main results obtained are as follows :

1) Rectangular elements are effective only to mono-circular openings and triangular elements may be applied to another case of openings. The differences of temperature around mono-circular openings between two methods of calculation by rectangular and by triangular elements are 5°c in maximum after 24 hours.

2) In the case of the rate of cooling temperature of openings surface more than -10°c/hour, every temperature distribution around underground openings is nearly same after 5 days.

3) As a heat transfer coefficient exist practically between a room and surface, it doesn't always follow that surface temperature is -162°c constantly. But from safety design view point of underground openings, temperature distribution should be calculated under condition of constant surface temperature -162°c.

(G-7, H-5)

(22) Stability Analysis of Multi-Underground Storage Caverns for Fuels and Reinforcements

Hibino, S.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 51-55, 1980,

Stability analysis on behaviour of rock masses around caverns for fuels was carried out using finite element method. The method of the analysis is able to take into consideration several factors such as characteristics of failure envelope, non-linear deformability of rock masses, and excavation stages etc..

A size of oil storage caverns would be rather small, because of not so good rock conditions in sites near seaside. The author, therefore, has set the size of 15m in breadth and 22.5m in height.

Through the simulation of excavation for multi-undergound caverns, the following results were obtained;

(1) Distance between adjacent caverns

The adequate distance between caverns has been shown to be equal or more than an average value of a height and a breadth of caverns. If the distance would be smaller than that, sizes of relaxed zones would be enlarged due to effects of excavation for adjacent cavities.

(2) Pore pressure

Filling fuels into caverns produces pore pressure in rock masses around caverns, which causes sizes of relaxed zones grow large. The effect of pore pressure is very remarkable.

In the case of pore pressure of 7 kg/cm^2, the depth of added relaxed zones was about 3m which was nearly equal to the depth of relaxed zones formed during excavation.

(3) Reinforcement

Reinforcement of rock bolts or pre-stressing bars increases safety factors for sliding in relaxed zones. The author presented one method of evaluating safety factor with the idea that the safety factor should depend on such factors as residual strength, stress distribution, shapes of relaxed zones, pre-stressing and strength of reinforcements, etc..

(G-4, H-5)

(23) Influences of "Underground Erosion" on Instability of a Crystalline Schist Slope

Sassa, K., Takei, A. and Marui, H.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 56-60, 1980,

As the causes of instability of slopes, 1) Change of slope profile (toe erosion, artificial excavation, etc.) 2) Increase of pore pressure are firstly listed. Secondly weathering is mentioned as a factor to decrease the strength of rock in a long term. The authors have reported before that weathering, drop-off of fine particles by infiltrating water and underground erosion by ground water can cause vertical subsidence and the liquefaction of subsided mass in the reference 1) 2).
However, "underground erosion" has hardly been studied both in engineering field and geographical field up to now. In a crystalline schist slope, its slope inclination is so great as about 30°, and its rock is much permeable because it is crushed by active tectonic movements and originally has numerous schistosity. Accordingly discharge and velocity of ground water are supposed to be great, then "underground erosion" necessarily should be great there. We have researched "underground erosion" from underground structures, behaviors of ground water and movements of the ground in a crystalline schist landslide "Zentoku" of the Shikoku island in Japan.

The seismic exploration has disclosed that there are some crushed zones and underground valleys in the landslide, and they facilitate the flow of ground water.
The measurement of the ground water velocity by a seismograph(reference 5) & 6)) showed that the velocity of ground water is so high as the order of m/sec. after a typhoon, and ground water rather exclusively flows in some water paths. The observation of the ground water levels also demonstrates that ground water flows primarily in water paths at a few levels, and the discharge and the velocity of ground water in such a water path should be rather rapid. Therefore, it would be probable that sometimes failures take place in the water path and sediments deposit there, and sometimes these deposits are retransported in the sililar manner to the sediment trasportation on the surface of the ground. The observation of the ground water levels uncovered the phenomenon of occasional sudden lifts and sudden drops of the ground water level during no change of precipitation which should corresponds to the above-mentioned presumption. This phenomenon strongly suggests the existence of active underground erosion.

Sassa et al.[3)7)] have developed "shear displacement meter" which measures horizontal and vertical shear displacement between two points. We set 40 shear displacement meters continually in a crossing line of the Zentoku landslide, and have observed them from 1974 to the present every week.
According to the results, vertical movement exceeded horizontal movement in three years during five years of 1974-1978, especially the vertical movement in 1975 was much greater than the horizontal one, and the shape of both movements do not correspond one another. This implies the existence of distinguished vertical subsidence independent from landslide movement parallel to slope. The independent vertical subsidences have been observed repeatedly in these five years. The repeated vertical subsidence can not be interpreted by pore pressure because the virginal subsidence must recover the bearing capacity and pore pressure can not progressively increase. While underground erosion progressively decreases the bearing capacity of the ground. Therefore, the repeated vertical subsidences must be one of the evidences of the active underground erosion.

As regards the moving sediments under the ground, fortunately a drainage well in the landslide was sheared by a sliding surface in 1976 and the sliding surface is formed through a water path there. Then ground water flows in and out the drainage well through the water path like a stream. The transported sediments have deposited there, and the grain size of the deposits is about 0.1-50 mm.

(G-4)

(24) The Comparison of Observed Result with Calculated One with regard to Deformation of Excavated Slope

Kitahara, Y., Tokue, T. and Motojima, M.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 61-65, 1980,

The observed behavior of deformations during the excavation of slope is reported, from the view point of the comparison with those obtained from numerical calculation. The observation were carried out at the site of BUZEN Switch Yard where a large scale slope excavation had been done by Kyushu Electric Power Co.. On the other hand, numerical approach was made by using the incremental stress analysis of two dimentional F.E.M. in which non-linearity of stress-strain relation could be taken into consideration.
The conclusion drawn in the report are as follows;
1) The excavated slope are geologically composed of tuff-granullar stone, tuff and tuff-sand stone. The rockmasses are, generally speaking, said to be soft ones.
2) The mecanical properties of the rock masses are as follows;
Range of density; 1.7 ~ 2.1 (t/m^3)
Range of cohesion; 78 ~ 137 (t/m^2)
Range of friction angle; 38° ~52°
Range of deformability; 40,000 ~ 110,000 (t/m^2)
3) The experimental function, which represents the stress-strain relationship under the condition of stress path of un loadings, is proposed. The difference of coefficient of deformability between loading-conditon and unloading-condition is found to be to a certain degree great.
4) Displacements within the span of 10 meters are measured in the rockmasses by enbedded deformaters. The maximum observed displacement, from the beginning to the end of excavation, is about 5 mm. The value is registered at the bottom corner of the slope and its direction is perpendicular to the surface of the slope.
5) The observed displacement showed a sudden peak at the time of heavy rain fall. It can be said that a seepage flow in the neighbourfood of the surface of a slope has a great effect on the stability.
6) Eventhough the developement of displacement is a little greater in the case of calculation than in the case of observation during the beginning of excavation, at the final stage of excavation total displacements are almost the same in both cases of calculation and observation.

(G-4)

(25) Computer Program of Design for System Rock-Bolt Tunnelling Method

Yoshimura, H. and Tsuchiya, T.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 81-85, 1980,

JNR has been positively adopting so-called "System Rock-bolt Method" as a new tunnelling method. In order to improve it further, experimental research has been carried out to clarify the reinforcing mechanism of the rock-bolt and the calculation program for the design has been developed.

This report deals with the design program and includes the following;

1. Basic conditions for the programing.
2. Evaluation for the reinforcing effect of the rock-bolt.
3. Stability (Sliding)condition of rock-bolt.
4. Various structural models of the tunnel lining for Finite Element Method.
5. Time-dependent property of concrete lining.
6. Non-linear property of the surrounding rocks.
7. Time-dependent displacements and stresses of the tunnel structures.
8. Procedure and flow for the analysis of the tunnelling method.

This program is now successfully used for the tunnels such as Narita Air Port Tunnel and Usami Tunnel, which are extremely difficult to construct by means of usual method, and also used for preparation of the standard design of the system rock-bolt tunnels.

(G-0, H-5)

(26) Measurement and an Example of Numerical Analysis for Miyana Tunnel Excavated in Semi-Hard Rock with NATM

Yoshimura, H., Yuki, T., Yamada, Y. and Kokubun, N.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 86-90, 1980,

This paper reports the measurement and FEM analysis of Miyana Tunnel which is a double truck tunnel (total length; 1800m) under construction on the Uetsu Truck Line of Japanese National Railways. Of the total length, a 1250m section is being excavated in dolerite with full face New Austrian Tunnelling Method (NATM). To double truck railway tunnel (cross section area; 60.9m²) in semi-hard rock NATM has scarcely been applied in Japan, so very little data exists on the behavior of the rock mass under such conditions. Therefore the authors report the measuring results and an example of numerical analysis of this tunnel, expecting them to be availed for other measurements and predimensionings under similar conditions.

Physical properties of dolerite (sample) are as follows; unconfined compressive strength=280~750kg/cm², modulas of elasticity=1.6×10^5~3.9×10^5 kg/cm², elastic velocity-4.7~5.3km/s.

Rock movements are measured with convergence measuring device and multiple-point borehole extensometers, and results of the measurement show that rock movements are extremely small (maximum value: about 1mm) and cease early (within a week). The stresses acting along the rock bolt and in sprayed concrete are also measured with electrical resistance strain gauges and hydraulic pressure-cells, and the results show that they are considerably lowerer than those designed.

Physical properties of dolerite (sample) adopted, simple elastic FEM analysis was carried out as numerical analysis. Consequently good correspondence was recognized between the values measured and those calculated, and plastic zone was considered not to exist in the surrounding rock mass.

The results in this paper apply only to the rock conditions in Miyana Tunnel so before any general theories could be developed many more measurements and numerical analyses under similar conditions would be needed.

Based on the results from the measurement and FEM analysis, the following conclusions can be drawn regarding the tunnel excavated in dolerite with NATM.

(1) The behavior of rock mass and supports in the double track tunnel excavated in semi-hard rock (dolerite) with NATM has clarified to a certain degree.

(2) Pre-dimensionings of NATM in semi-hard rock can be carried out with simple elastic FEM in some cases.

(G-4, H-5)

(27) Measurement at No. 2 Hiraishi Tunnel, Excavated by the NATM in a Completely Decomposed Granite

Yoshimura, H., Sasaki, Y., Seki, J. and Nakamura, T.

Proceedings of the 13th Symposium Rock Mechanics, JSCE, pp. 91-95, 1980,

We have applied the NATM to №2 Hiraishi tunnel ($\ell = 245m$).
This tunnel has a slight overburden (0～14^m height) and the soil condition is as follows.

geology	;	completely decomposed granite
physical properties	;	
internal friction	,	$\varphi \fallingdotseq 30^\circ$
cohesion	,	$C = 0.2 \sim 0.8 Kg/cm^2$
deformation modulus	,	$E = 60 \sim 160 Kg/cm^2$

The area of the cross section is about $90m^2$

We have excavated this tunnel by singular 3 bench cut method for the safety against soilfall from the arch.

Measured items are as follows.

- settlement at ground surface
- settlement at tunnel crown
- convergence H_1, H_2

} at every measuring sections

- contact and concrete stress of shotcrete
- normal and bending stress of H-steel support
- normal stress of rock bolt
- deformation in ground

} at the section

(G-4, H-5)

(28) The Behavior of Rockbolts Fully Bonded through the Plastic Zone

Hata, S., Tanimoto, C., Nishihara, A. and Kariya, K.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 101-105, 1980,

Recently the application of rockbolts has been developed as the prime support, and it is very important to know the interaction between rock and rockbolt through plastic zone. In practical tunnelling through soft rock whose competence factor becomes quite low such as below 1.0, so called expansive behavior happens and gives difficulty in supporting, and it is considered that this expansion of the ground is caused mainly by squeezing. So, analytical model for the calculation of plastic zone should be considered of strain softening behavior of the rock around the opening.

The correlation among the width of plastic zone, the displacement of the wall and plastic strain near the wall can be expressed plainly by substituting equivalent inner force, acting onto the wall, for bearing force which steel ribs,

systematic rockbolts and/or shotcrete lining give in the vicinity of mining face. Also, the decrease of the half dome action, being associated with the advance of the face, can be expressed by the introduction of dragging force acting on the wall.

Being based on these relationships, axial force and shearing force acting on the fully bonded bolt can be calculated by giving the stress increment, obtained by strain softening model, which causes between setting time of rockbolts and steady state far from the face, to FEM-model.

Consequently, the following results are obtained.

(1) In designing rockbolt system, the competence factor of the ground and the bearing capacity of the support are main parameters. It is confirmed by the numerical analysis that the width of plastic zone, having tight relationship with the stability of an opening, shows big difference in the case of low competence factor such as below 1.0 even if bearing capacity varies a little.

(2) When the distribution of axial force along the rockbolt is measured, the cross section showing peak value does not always agree with the elastic-plastic boundary, but it does only when the ancoring length of a rockbolt is longer than the pickup length. And these lengths can be measured by applying a long rockbolt reaching beyond the double distance of plastic zone to be presumed.

(3) Though even the rockbolt whose end does not reach to elastic zone shows some effect, the optimum size of systematic rockbolts is considered to be 1.5 - 2.0 times longer than the width of plastic zone in order to obtain steady effect as the permanent support.

(G-4)

(29) Earth Pressure Determination of Tunnel Lining Consisting of Concrete Segment

Sakurai, S.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 111-115, 1980,

The axial force and bending moment acting in tunnel lining can be back-analyzed from the measured deformations of the lining. This technique has already been well established as "Integrated Measuring Technique" for steel support structures. However, an applicability of the technique to concrete lining has not yet been verified, because of complexity of the mechanical properties of concrete.

The objective of the work presented herein is to demonstrate an applicability of the integrated measuring technique to concrete tunnle lining.

A concrete segment of tunnel lining is tested in laboratory under concentrated loading conditions. It is concluded from the laboratory investigations that the integrated measuring technique is sufficiently applicable to concrete linings. An accuracy of determining the stress resultants is very high if there exist no cracks. When cracks appear, the stress resultants are scattered. Even in this scattering case, however, a fairly good evaluation on the stress resultants can be possible, if the measurements are taken at the surface where no cracks exist. The maximum errors involved in this case may be approximately less than 20%. If the measurements are taken at the cracked surface, then the errors increase to 60 - 80 %.

This work presented herein was performed at the Swiss Federal Institute of Technology, Zurich, while the author stayed as an academic guest. The author wishes to express his gratitude to Dr. K.Kovari, the head of rock mechanics department, for drawing his attention to this problem. The laboratory tests were performed at EMPA, Duebendorf. The author also wishes to thank the staffs of EMPA for their cooperations for the laboratory tests.

(G-4, H-5)

(30) Numerical Analysis of Movement of Ground and Groundwater due to Tunnel Excavation

Ohnishi, Y. and Ohtsu, H.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 116-120, 1980,

Movement of ground and groundwater due to tunnel excavation is very important because of its engineering and environmental impact. The stress analysis of excavation and seepage flow analysis are often done independently. However, it has been recognized that the stress flow coupling effect should be considered seriously to know the actual behavior of the ground.

Here we have developed a new new method to solve the coupled stress-flow problem taking into account the saturated and unsaturated regions. Then the case of unconfined flow with free surfaces can be analysed. The governing equation was derived from Biot's consolidation theory. The finite element formulation was adopted using Galerkin's process.

In the case that a tunnel is fairly close to the ground surface, the surface settles and water table is lowered due to tunnel excavation. This problem was solved with a simple model to show the large potential of this proposed method. The movement of water table, settlement of ground surface, deformation of tunnel wall and stress changes of surrounding area were calculated at one time. The result was very satisfactory. (G-5, H-5)

(31) Three Dimensional Tunnel Model Test to Evaluate the Stress Conditions around a Tunnel Face

Inokuma, A. and Ishimura, T.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 121-125, 1980,

The earth pressure on tunnels is not clearly known yet. There are several ways to make it clear. Model test is one of them. The authors carried out three dimensional tunnel model tests.

1.Law of Similitude

We used dimensional analysis to get the law of similitude concerning this model test and found 5π numbers (table 2). In this case we ignored π_4.

2.Experiments

Fig 2 and 3 show the experimental equipment. Roughly speaking, we excavated a tunnel through earth in a tank (1m x 1.5m x 0.5m). We mesured vertical pressures both on and around the tunnel.

In order to satisfy $\pi 2$, we needed weak and heavy material for the model's earth. We found that sand with 2% water content,which had a little cohesion resulting from its suction effect, was sutable for this purpose.

Fig 7,8 and 9 show the results of these experiments.

3.Comparison of the Experiments with a In-Situ Measurement

We compared the results of the model tests with the results of field mesurements, which were done at Kaizuka Tunnel Construction Site.

Table 2

$\pi 1$	H/D
$\pi 2$	C/rL (L=D or H)
$\pi 3$	tan
$\pi 4$	d/D
$\pi 5$	T/rL (L=D or H)

Notation	and its dimension	force	length
H	earth covering	0	1
D	tunnel diameter	0	1
d	allowable ground loosening	0	1
r	unit weight of earth	1	-3
C	cohesion of earth	1	-2
ϕ	friction angle of earth	0	0
T	earth pressure on tunnel	1	-2

(G-4)

(32) Approach for F.E.M. Analysis Considering Process of Tunnel Excavation

Kano, Y., Fukushima, H. and Kaneko, N.

Proceedings of the 13th Symposium on Rock Mechanics, JSCE, pp. 126-130, 1980,

On the excavation of underground structures (ex. tunnel), the safety and the economy obey the correct evaluation of "Lining" and "Ground" around the tunnel.

To evaluate the behaviours correctly, F.E.M. non-linear program was developed under the several factors which make influence to the behaviours. The factors are

A) Arrangement of excavation
B) Stress release ratio varied by tunnel advance (support effect of the face)
C) Installation timing of support system
D) Behaviours of young shotcrete
E) Reduction of loading capacity of rockbolts by slip
F) Damage zone by blasting, etc.

Three tunnel examples were calculated about the following items under valiable loading of excavation,

1) Tunnel convergence
2) Settlement of tunnel crown
3) Stress distribution of lining
4) Crack condition

The former three items are considered satisfactory in comparision with the measured value. In case of the analysis of "Crack condition", however, the estimation of tunnel lining model (ex. shotcrete, rockbolt) must be studied still more.

(G-4)

(33) Geotechnical Properties of Mudstone in Relation with the Mechanism of Swelling Rock Pressure on Tunnels and Some Problems concerning Earth-Rock Dams

Nakano, R.

Tsuchi-to-Kiso, JSSMFE, Vol. 28, No. 7, pp. 37-43, 1980,

The mechanism of swelling rock pressure on tunnels often experienced in mudstone is discussed based on the fundamental geotechnical properties of mudstone as well as the concept of critical state soil mechanics and it is shown that the swelling rock pressure is caused not by the swelling pressure of montmorillonite but by the squeezing of broken rocks which behave as clay soil with low post-failure strength.

A brief discussion is also made on some important geotechnical problems such as slide and deformation of mudstone foundation of earth and earth-rock dams as well as the disintegration of mudstone used as fill materials.

(G-4)

(34) The Plate Bearing Tests on the Multi-Column Type Foundation in Ohnaruto Bridge

Endo, T., Yamaguchi, K. and Nomura, N.

Tsuchi-to-Kiso, JSSMFE, Vol. 28, No. 11, pp. 43-48, 1980,

In the case of Ohnaruto Bridge, multicolumn-type foundations are being constructed for the main towers and the bent pier. The plate bearing tests were held at the bottom of the excavated multicolumn-type foundation after the ground water had been dried up.

This report mainly describes the method of the plate bearing tests and the strength classification of foundation rocks based on the results of these tests.

(G-3)

(35) The Actual Plant in Kikuma Based on the Underground Oil Storage System

Sakurai, T.

Tsuchi-to-Kiso, JSSMFE, Vol. 29, No. 1, pp. 15-22, 1981,

In Japan, almost all oil storage stations have been costructed based on the on-land tank system, however, considering the difficulty in securing sites for such stations, it became necessary to develop and utilize a new oil storage system which takes into account the characteristics of each location in terms of the most effective use of the limited area.

The actual plant in KIKUMA which we introduce in this report, is a horizontal water-sealed oil pit (tank capacity; 25 000 kℓ), and is designed to improve the underground oil storage system in Japan by evaluating and confirming it's safety and adaptability through various tests and experiments.

(G-4, H-5)

(36) Construction of Large LNG In-Ground Storage at Sodegaura Terminal

Goto, T. and Takahashi, T.

Tsuchi-to-Kiso, JSSMFE, Vol. 29, No. 1, pp. 29-36, 1981,

Liquefied natural gas (LNG) became the focus of attention as the source for clean energy. Increasing demands for LNG require developments of technologies for construction methods with higher capacity and safety. In-ground tanks are gaining the preference as of the Sodegaura receiving terminals in Chiba prefecture known not only for its world-largest capacity but also for its safetiness, environmental considerations, and the effective land utilization. Furthermore, with the aid of the super-deep slurry wall, Tanks with the largest capacity of 130 000 kℓ are under construction. This is a report on the design and construction of these LNG in-ground tanks.

(G-4)

(37) Approaches to Hydraulic Analysis for Underground Cavern

Sato, K.

Tsuchi-to-Kiso, JSSMFE, Vol. 29, No. 12, pp. 45-50, 1981,

Hydraulic analysis and ground water simulation concerning the behaviors of ground water around the caverns for purposing the electric power station and the fuel rock store have been carried out by the finite element method or finite difference method in recent years. Hydraulic analysis method itself in addition to the accuracy and reliability of field investigation techniques must be developed in future at present. This paper described several fundamental characters related with the ground water flow around the cavern and how to approach to hydraulic analysis for this kind of flow by referring some new studies.

(G-5, H-5)

(38) A Fundamental Study on Roof Fall Phenomenon

Okamura, H., Sugawara, K., Konatsu, H., Kaneshige, O. and Obara, Y.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 95, No. 1097, pp. 387-392, 1979,

For the purpose of the study on the mechanism of roof fall in the long wall mining, the authors have first studied fundamentally the stability of the roof beam which is separated from the upper seam and deforms only by its dead weight and secondly studied experimentally the roof fall phenomena by the model test through the use of the centrifuge. It is found from these studies that when the separated roof beam from the upper seam deforms only by its dead weight, the tensile fractures easily break out at the down side of roof center and at the upsides near the ends of flat cavity, but the roof fall does not occur at least unless the compressive yieldings iniciate at the bearing points in this cracked roof beam under the following condition, that is

$$Q = 0.5\, S_c\, D^2 / L$$

where Q is the total dead weight, Sc is the compressive strength, D is the thickness of roof beam and L is the length of roof. In the case of very brittle rock roof, the roof fall occurs on this condition, but in case the plastic bending takes place before the collapse, the roof fall is caused by the compressive fracture just over the central tension crack under the following condition, that is

$$Q = 2\, S_c\, (D - d)^2 / L$$

where d is the deflection of roof.

(G-4)

(39) An Elasto-Plastic Analysis Applicable to the "Strain Softening" Materials, - Rock Mechanics Studies on the Underground Excavation in Soft Rock Mass (1st Report) -

Yamatomi, J., Shimotani, T. and Yamaguchi, U.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 95, No. 1100, pp. 721-726, 1979,

The investigations on the progressive failure around the underground openings will provide useful informations for the mining design. For this purpose, some preliminary studies have been carried out, and the following results have been obtained.

(1) The constitutive equation suitable to the rocklike materials has been derived from the mathematical theory of plasticity, on the assumptions that the extended Von Mises' yield criterion and the associated flow rule are applicable to those materials.

(2) The applicability of the above theoretical constitutive equation has been confirmed by the confined compression tests.

(3) A finite element method for the stress analysis in the rock mass composed of the 'strain softening' materials has been developed, and the availability of this method has been verified.

(G-1)

(40) Distribution of Temperature in Rock Surrounding the Wet Airway, - Estimation of Temperature and Humidity of Underground Air Current (1st Report) -

Amano, K., Yamashita, H. and Kawabe, K.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 95, No. 1101, pp. 781-784, 1979,

A procedure by the finite difference method has been developed for estimating the heat flow from the wet surface of a mine airway into air.

This procedure makes it possible to estimate the temperature at any point in rock surrounding the wet surface of airway and to estimate both the temperature and humidity of air current at any time after the ventilation is started.

As a first step, the distributions of temperature in rock were calculated at the several periods of time up to 10 years from the beginning of ventilation.

The conclusions obtained are as follows:

1) The cooling rate of temperature at the wet surface of airway is higher than that at the dry surface of airway. Therefore, the surface temperature on the wet rock-wall of airway is lower than that on the dry rock-wall.

2) The surface temperature on the wet rock-wall of airway is lower than the temperature of air in case of more active water-vaporization from the rock-wall.

The estimation of the temperature and humidity of air current is to be dealt with in the next paper.

(G-7)

(41) The Effects of Roadway Shape and Weak Floor on Roadway Closure, - Fundamental Study on Roadway Closure (1st Report) -

Ihara, M. and Matsui, K.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 95, No. 1101, pp. 785-789, 1979,

The effects of roadway shape and weak floor on roadway closure were studied with scale model tests, using a sand-plaster mixture as model rock material.

In addition, the FEM analysis, taking a fracture criterion into consideration, was conducted to compare with these test results.

The results of model tests and the FEM analysis indicated the following conclusions:

(1) The thicker the weak floor becomes, or the more the applied pressure increases, the greater the roadway closure becomes.
(2) When roadway has the weak floor, the formation of fracture zone in the floor promoted the roadway closure.
(3) Circular roadway deformed with less amount than arched and square ones.
(4) The results of FEM analysis coincided with the experimental results qualitatively.

(G-4)

(42) Variation of Temperature and Humidity of Air Current Passing through a Partially Wetted Airway, - Estimation of Temperature and Humidity of Underground Air Current (2nd Report) -

Amano, K., Yamashita, S., Kawabe, K. and Hiramatsu, Y.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1103, pp. 13-17, 1980,

A procedure by the finite difference method was developed for estimating the heat from the wet surface of a mine airway into air.

In the previous paper, the results of the computation for the distributions of temperature in rock at the several periods of time from the bigining of ventilation were reported.

In this report, the modified procedure for estimating the variations of temperature and humidity of air current was proposed by noting that these quantities were more affected by the wet part of the mine airway than the dry part.

After the comparison of the results by the above procedure with the results of in-situ measurements, this procedure was proved to give the estimation with a sufficient accuracy for the temperature and humidity of the air current passing through the partially wetted mine airway.

(G-7)

(43) Problems of Temperature Distribution and Heat Flow in Rocks around Roadway, - Applications of Finite Difference Method to Calculation of Temperature of Mine Air (2nd Report) -

Yanagimoto, T. and Uchino, K.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1104, pp. 71-77, 1980,

In order to predict the temperature of ventilation air in mines it is essential to calculate accurately the temperature distribution in rocks around a roadway and the heat flow into the air current. Many authors have considered the problem of unsteady heat conduction. However, in previous studies many assumptions were made to simplify the problem, and some of the assumptions have never been discussed quantitatively. Consequently, there are uncertainties about the validity of these assumptions.

In this point of view, the authors examined the following assumptions by means of finite difference method, forcusing on the problem in coal mines;

(a) circular roadway
(b) isotropic rock, and
(c) homogeneous rock.

Examination of these assumptions leads to the following conclusions;

(a) To a good approximation the total heat flow is the same as that for a circular roadway having the hydraulic diameter of the actual roadway.

(b) The anisotropy of coals and shales are not negligible. However, a good approximation is obtained by calculating the heat flow for a roadway driven in isotropic rock whose thermal conductivity is the geometric mean of the thermal conductivities parallel and vertical to the bedding plane.

(c) When a roadway is driven into the coal seam, the coal seam has a great effect upon the temperature distribution in rocks and the total heat flow. In the present paper a method is proposed for modifying the equation for prediction of air current temperature to take into consideration the effect of the coal seam.

(G-7)

(44) Proposal of Grid-Model Method for Three-Dimensional Analysis of Ground Movement due to Mining, - Study on Ground Movement Caused by Underground Opening (1st Report) -

Nishida, T., Esaki, T., Kimura, T. and Shibahara, T.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1109, pp. 455-460, 1980,

For the purpose of three-dimensional analysis of rock pressure due to mining, G. Everling et al.presented the grid-model method in 1972. In this report, the method of three-dimensional analysis of ground movement due to mining, which is based on Everling's model, is proposed.

By the grid-model method, the ground is divided into finite rectangular prismatic elements and we have only to solve the equation of equilibrium for the forces which act on each element. Everling's model is improved by the present method in respect of taking into consideration of body force of each element, boundary location of model, proper boundary condition and so on.

Moreover, through the practical calculation for some types of room-and-pillar mining, the characteristics of this method have been made clear as follows:

(1) This method is effective for the types of mining which can not be treated by conventional two-dimensional analysis such as plane stress and plane strain.
(2) General ground movement such as surface subsidence and convergence between roof and floor can be analyzed as well as rock pressure.
(3) In the practical calculation, because the needful region size of computer can be small, the model can be divided into a great number of elements and it takes short processing time.

(G-2)

(45) Prediction on the Drainage Control by Mine Sealing (3rd Report), - Studies on the Technique to Prevent the Pollution at Closed Mines (6) -

Terada, M., Oka, Y., Kuroda, K., Nishida, Y., Nakano, K. and Katagiri, M.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1114, pp. 863-870, 1980,

At two closed mines, Kanagato (in Yamaguchi Pref.) and Takahi (in Yamagata Pref.), application of the mine sealing has been carefully considered in order to prevent the pollution due to the underground mine water drainage, now. Authors tried numerically to estimate the amount of mine water drainage in each of these mines.

First, a numerical analysis on the ground-water infiltration was carried out on the cone-shaped ground model with a gentle slope by using the finite element method on a field problem, and consequently characteristics of the free ground-water surface and the effluent seepage from the water-bearing zone in this model were derived.

Next, a hydrological survey for distributions of the source and the water flow on the surface stream was carried out on each of these mine areas, and consequently the mean recharged value of ground-water and the apparent permeability of ground were decided.

Lastly, the amount of underground mine water drainage, when the sealing would be performed in each mine, was predicted by the computational method developed previously, as described in the 1st and 2nd reports. As the result, it was predicted that on the amount of mine water drainage about 40% in Kanagato Mine and 20 ~ 50% in Takahi Mine could be decreased by sealing, respectively. Moreover, many useful data concerning the mine sealing were obtained.

(G-5)

(46) Analyses of the Ground Movement Caused by the Longwall Mining and a Consideration about the Mechanism of Coal Burst, - A Study on Coal Burst (2nd Report) -

Sugawara, K., Kimura, O., Ohara, Y. and Okamura, H.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1115, pp. 19-25, 1981,

First, the features of the ground movement caused by mining a horizontal coal seam are studied by examining the results of the elasto-plastic analysis carried out by Finite Element Method. It is found that the vertical stress distribution in the coal seam, except near the longwall face, is characterized by the width c^*, as shown in Fig. 7, which is defined by equation (9), namely it is the amount of the vertical load P^*, newly acts on the coal seam by mining, devided by the initial vertical stress p_y. As a matter of course, c^* is equal to the half length of the excavation unless the contact between the hangingwall and footwall occurs in the mined area. But after the contact, it is approximately proportional to the length of the cave behind the longwall face and to the rigidity of the hangingwall.

Secondary, the mechanism of coal burst at the longwall face are studied by analyzing the stress histories and the plastic behavior of coal in front of the face, in the case that the coal seam is sandwiched by the rigid hangingwall and the relatively soft footwall as like as in the coal burst area of Miike mine. In the case that the internal friction angle of coal is high and the hangingwall and footwall restrict the swelling of coal, it is found, the plastic area in front of the face is reasonably narrow, the center part of the face partially swells and the high stress concentration appears near the face. In this case, if the slides occur along the boundaries among the coal seam, the hangingwall and the footwall, the plastic coal at the face is restrained the vertical compression of which the value is inversely proportional to the rigidity of footwall. When this plastic compression exceeds the limit strain, permissible for coal before the brittle rupture after the yielding, we conclude, the coal is violently destroyed at the face.

(G-2)

(47) The Relations between Coal Bursts and the Roof Subsidence, in the Level Entries Caused by Mining, - A Study on Coal Bursts (3rd Report) -

Kimura, O., Sugawara, K. and Okamura, H.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1116, pp. 89-94, 1981,

The features of the roof subsidence in the level entries, caused by mining a horizontal coal seam, are studied by analyzing the results obtained by survey in the coal burst. area of Miike mine. It is concretely found out that the progress of the roof subsidence in the level entries not only concerns with the distance from the longwall face and the change of geometrical shape of the mined area, but also concerns with the discontinuities in the roof, as shown in Fig. 5 and 6. Correlating with the length of the level entry, where the roof subsidence is growing up with the face advance, the frequency of coal burst increases as shown in Fig. 9 and this length is related to the intervals of the discontinuities as shown in Fig. 7. In the case that the rigid hangingwall is directly lying on the coal seam, we conclude, this length reflects the magnitude of the pressure acts on the abutment.

(G-4)

(48) Rock Bolting In-Situ Test at Yubari-Shin Colliery

Machida, K., Fukushima, A., Nishimura, S. and Miura, K.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1117, pp. 173-178, 1981,

In Yubari-Shin Colliery, main roadways are driven in the thick Horokabetsu shale below the workable coal seams at the depth of about 1000m from the surface. The roadways converge seriously, particulary due to floor heave, because rock strength is weak against rock pressure, and many maintenance works are carried out for the roadways.

For the purpose of relief of roadway maintenance works, a rock bolting test by Rock Bolt Setter was carried out in addition to the steel arch support (weight 34.7 kg/m) in the present operation. Rock Bolt Setter used in this test is equipped with 1 power unit, 1 boom, 1 universal roofbolting turret, 1 hydraulic rotary drill and 1 hydraulic rotary bolting motor mounted on a chassis of 642 H loader.

The test results were as follows:

1. The capacity of bolting by Rock Bolt Setter was 45 bolts/shift (average) in a 15° inclined roadway, 50 bolts/shift (average) and 65 bolts/shift (maximum) in a level roadway.
2. By system rock bolting, convergence of roadways was improved to about half compared with the steel arch support only.

(G-4)

(49) A Fundamental Investigation of Stress and Deformation in Slope, - Stability of Rock Slope (1st Report) -

Nishida, T., Esaki, T. and Shibata, K.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1120, pp. 437-443, 1981,

It is one approach to estimate slope stability to know the stress and deformation in the region of the slope. The factors affecting slope stability could be as follows: mechanical property of rock, angle and height of slope, horizontal curvature, initial stress and others. We clarified these factors are how to affect slope stability by the finite element analysis. The results may be shown below.

(1) The stress near the toe concentrates at slope angle above 45° and increases in proportion to height of slope.
(2) The slope with convex curvature in the projection to horizontal plane is more stable than the slope with straight one. This trend is remarkable when the ratio of radius of curvature to slope height is lower than 0.5.
(3) In case of high initial horizontal stress, the stress near the toe increases in proportion to the lateral coefficient K and does not increase by slope angle. And the increase of tensile stress region at the crest is easy to make crack there.
(4) As the excavation advances, the failure zone extends along the surface of slope and makes the slope unstable.

(G-2)

(50) Measurements of Deformation and Variation in Stress of Rock with Progress of Secondary Mining in Yanahara Mine

Hiramatsu, Y., Aoshima, T. and Kameoka, Y.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1121, pp. 533-538, 1981,

In the Yanahara mine, measurements of deformation and variation in stress of rock were carried out with the progress of the secondary mining of the lower ore body, to supply materials for investigation of a safe mining with high extraction but without surface damages. Absolute rock stresses were also determined. Examination of the results obtained, in consideration of the earth pressure phenomena observed, yielded the following conclusions.

During the primary mining and in the early stage of the secondary mining, the deformation of rock, which might be elastic, could be monitored by a photoelastic stressmeter. In this stage some rock failures took place.

After the secondary mining progressed considerably, rock failure rarely occurred, but large and complicated deformation of rock, which might be elasto-plastic, were monitored by an extensometer and an inclinometer.

By the stress relief technique, it was found that the original stress in the east and west direction was about three times the vertical one, and that even when a greater part of the ore was already mined out, there occurred high stress concentration in pillars and rock, which suggested soundness of the pillars.

(G-2)

(51) The State of Deformation and Failure of Roadway Driven in Discontinuous Rocks, - Fundamental Study on Roadway Closure (2nd Report) -

Ihara, M., Matsui, K. and Ichikawa, Y.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1123, pp. 923-928, 1981,

When a mine roadway is driven in discontinuous rocks, it may be expected that the stability of the roadway will be diffrent from that driven in continuous rocks.

The effects of horizontal discontinuities on deformation and failure of a roadway were studied with both the Finite Element analyses using the joint element and scale model tests using a sand-plaster mixture as a model rock.

The results from the FEM analyses and model tests showed that the state of deformation and failure of a roadway driven in discontinuous rocks is much affected by the behaviour of the discontinuities which depends on the properties of the rocks themselves, the primitive stresses (applied pressures) and the properties of the discontinuities.

(G-2)

(52) Measurement of Rate of Heat Transmission from a Ground Bearing Hot Mineral Water to the Air Current in a Drift Excavated in the Ground

Amano, K., Hiramatsu, Y., Ogino, S. and Mizuta, Y.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1123, pp. 929-935, 1981,

In the Toyoha mine the ground temperature is very high owing to hot mineral water found in the ground. Several veins bearing zinc and lead ores have been mined down to the depth of 300m from the level of the main entry. Since 1974, the 450m level of Tajima vein has been developed by driving a drift, where the rock temperature is from 80 to 90°C.

To obtain fundamental data for designing economical cooling, the heat balance in the drift was investigated by several measurements in August of 1974 and 1976, and continuously from August 1978 to July 1979. From these investigations the following informations were obtained.

The heat transfer through rock affected by hot mineral water to an air current is, against our expectation, not great, and is at most twice as much as a theoretical heat transfer through rock unaffected by hot mineral water. However in the case that an air current is in contact with hot water which flowed or seeped into the drift, a great heat transfer to the air current, sometimes ten times the theoretical heat transfer from rock unaffected by hot mineral water, will take place.

For effective cooling it is advisable to prevent inflow or seepage of hot mineral water, to prevent the air current from direct contact with hot water, and to use chilled water efficiently.

(G-7)

(53) A Case Study of the Landslide Happened on a Limestone Quarry

Yamaguchi, U., Shimotani, T., Shimomura, Y. and Ando, Y.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1125, pp. 1157-1162, 1981,

This is the report of the landslide happened on 20th of September, 1973 at the Kagemori limestone quarry, Saitama prefecture. The slide started at about July of 1972 and it took over one year to final slide from the first finding of the crack on the slope. This report includes the record of the displacement of crack opening observed at the crack on the failure slope and the analitical discussion on the slide.

(G-4)

(54) Experimental Study on the Floor Lift of Coal Mine Roadway Driven in the Weak Rock (1st Report)

Shimada, S., Hokao, Z. and Sugiura, T.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1126, pp. 1241-1244, 1981,

Japanese Coal Mines are suffering from the severe floor lift of roadway and many attempts have done to find the suitable and effective controlling method of floor lift. But until now decisively effective method is not yet established.

The model experiments, using equivalent materials, of the floor lift occurring when the coal face passed over the roadway driven in the weak rock were carried out. The authors investigated the following items and reported some results.

(1) The behavior of the weak rock around the roadway.
(2) The relations between the intensity of the floor lift and the depth of roadway up to 1000m.
(3) The effectiveness to control the floor lift by floor bolting. The relations between length of bolt and the intensity of the floor lift.

(G-4)

H. [Design, Construction and Behaviour of Engineering Works]

(1) Construction of the Kan-Etsu Tunnel

Ohmori, I. and Umino, Y.

Journal of the Japan Society of Civil Engineers, Vol. 64, No. 6, pp. 23-31, 1979,

The construction of the Kan-Etsu Tunnel, the longest driveway tunnel of 11 km in Japan, is now to its climax. The design and construction process are reported in this article.

(H-5, K-4, K-11)

(2) The Use of Asphalt in Dam Cores

Kasahara, A., Ishizaki, Y. and Sugawara, T.

Journal of the Japan Society of Civil Engineers, Vol. 65, No. 5, pp. 27-34, 1980,

Due to the shortage of favorable soil for dam cores, the use of asphalt mixture in cores of fill-type dams is considered recently. This paper clarifies the desirable properties of the asphalt mixtures and presents the method in designing and checking the safety of cores. The example of the application is also mentioned.

(H-4)

(3) Development and Application of Silica-Sol Grout in Construction of Nakayama Tunnel of the New Joetsu Trunk Line

Sasao, T., Suga, T., Tutiya, S. and Shimada, S.

Journal of the Japan Society of Civil Engineers, Vol. 65, No. 10, pp. 61-67, 1980,

The construction of the Nakayama Tunnel at the Takayama Section has required developing a new grouting technique to solidify soft ground under action of water pressure with preserving environmental condition. This article is to report the newly developed grouting technique using silica-sol grout of suspension-liquid composition type. Its principle, experimentation and the result of practical application are depicted together with the remaining problems and possible solution to them.

(H-5, K-2)

(4) Ground Behavior Containing of Completely Decomposed Granite by New Austrian Tunnelling Method (NATM)

Yoshimura, H. and Sato, T.

Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 71-75, 1979,

Daiichi Hiraishi Tunnel (ℓ=255m), and Daiichi Awasu Tunnel (ℓ=190m) for Tohoku Shinkansen Line were excavated by NATM. Both Tunnels have slight overburden, whose geology is completely decomposed granite.

Phisical properties of completely decomposed granite,

Single plain shear test	Friction Angle	$\phi = 30 \sim 34^\circ$
	Cohesion	$C = 0.3 \sim 0.4$ kg/cm²
Plate bearing test	Elastic modulus	$E = 160 \sim 300$ kg/cm²

Cross sectional area of Tunnel is approximately 90m² excavated by bench cut method taking 20~25 days from bench 1 to enclosure of Tunnel.

Behavior of Tunnel is as follows,

1) Settlement of ground was stopped by approx. 10days after enclosure of Tunnel whose final settlement values were at the range of 30~140㎜ depending on the overburden volume, amount of joints and conditions of excavation etc.

2) Displacement of excavated surface in the Tunnel occurred while excavation was proceeded, but it never occurred again in approx. ten days after Tunnel was enclosed. The maximam value of displacement was approx. 50㎜.

3) The displacement in the surrounding rocks measured by extensometer was found to be considerably large in each stratum. which was more than 4 meters apart from excavated surface The variation in the surrounding rocks measured by inclinometer was found about 40㎜, which was maximum when excavation of bench 3 was carried out and Tunnel section was enclosed.

(H-5)

(5) Design and Measurement of Okuyoshino Underground Power Station

Yamashita, M.

Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 76-80, 1979,

Okuyoshino power station is a pure pumped-strage one comprising six generating units, which is operated under a effective head 505m and has ultimately total installed capacity of 1206MW. The machine hall is an excavated cavity 20.1m wide, 41.6m high and 157.8m long and is located about 180m below the ground surface.

Geological surveys, rock tests and measurements were performed at the site. Then, the behavior of rock mass and the stress in the concrete lining were computed. A number of instruments were installed in the rock and concrete lining to ascertain the stress of rock obtained by the above method.

The results were as follows:

(1) The rock at the machine hall site was composed of chales, sand stones and the alternation of sand stones and chales.

(2) The values of the deformation modulus were 43 - 151 x 10^3kg/cm^2.

(3) The values of the shear strength were 8 - 19kg/cm^2.

(4) The values of the initial rock stresses were x_o = -77kg/cm^2, y_o = -74kg/cm^2 and z_o = -63kg/cm^2.

(5) Computed settlements of arch rock were about 15mm.

(6) Computed deformations of the side wall were 1 - 15mm.

(7) Computed stesses in the arch roof concrete lining were 10 - 60kg/cm^2.

(8) As the result of measurements, settlements of the arch rock were 14 - 16mm, deformations of the side wall rock were 1 - 15mm and stresses in the arch roof concrete lining were 20 - 80kg/cm^2.

(H-5)

(6) The Behaviour of Rock Masses around a Tunnel Excavated in Granite

Shinya, H., Takenaka, H., Suga, T. and Miyashita, K.

Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 106-110, 1979,

Measuring movements of rock masses around a tunnel excavated in granite, the authors investigated the behaviour of them. The size of the tunnel was about 8.5m in height and 8.5m in breadth. Two different measuring sections were settled, one of which was supported with about 5cm thickness shotcrete, and the other was supported with the same thickness shotcrete and system rock bolts which were fully bonded (ϕ24 x 3,000mm). In the latter section, 10 rock bolts were installed in one cross-section, and the total longitudinal distance was 9m with the rock bolt pitch being 1.5m. The items of measurements were convergence, the rock deformation and the velocity of seismic wave around the tunnel, and the loads in rock bolts.

The authors also carried out the elastic analysis by means of F.E.M. and triaxial compression tests of rock specimens to study the correspondence with the results of the measurements.

The main results obtained are as follows;

1. The plastic zones and a rheological phenomenon of rock were scarcely recognized. This is because the rock quality was good, and smooth blasting method was introduced. Therefore, it is considered that almost of the tunnel deformation was caused by the advance of the working face, with enlargement of joints in rock masses.

2. System rock bolts seem to make the rock mass tightly, sewing the rock together.

3. The fact that the distribution of the rock deformation in the non-bolted section have a good correlation to the distribution of the load in rock bolts in the system rock bolted section, is worthy of taking notice in considering the effect of the rock bolts.

4. There is a good correspondence between the results of measurements and elastic analysis when the young modulus of rock masses is estimated at $3.0 \times 10^4 kg/cm^2$. (The compressive strength of rock specimens is about $1,000 kg/cm^2$.) Even if the strength of the rock masses had been the same with the residual strength of rock specimens, failures around the tunnel would not occurred. But this is the theme of investigation in future.

These results show some of the property of granite rock masses, though they are obtained from observations of only one tunnel field.

(H-5)

(7) Displacement due to Tunnel Excavation and Geological Characteristics in Swelling Mudstone

Ohtsuka, M. and Takano, A.

Tsuchi-to-Kiso, JSSMFE, Vol. 28, No. 7, pp. 29-36, 1980,

We have been experienced heavily expanding mudrock at tunneling of Nabetachi-yama, located in Higashi-kubiki hilly regions of Niigata prifecture. Most of the trouble occured in excavating Shiiya-strata, which belong to tertiary period. The decrease of inner wall of circular section usually amounted to over more one meter, because of squeezing rock. Improvement of rockboling and shotcrete working proved effective to NATM.

Here we discribe some examples for movements of rock due to progress of excavation and try to make aproposal as to some references between expanding rock and its physical characteristics.

(H-5)

(8) The Settlement of Compacted Soft Rock-Fragments and the Countermeasure

Shima, H. and Imagawa, S.

Tsuchi-to-Kiso, JSSMFE, Vol. 28, No. 7, pp. 45-52, 1980,

Long-time-lasting settlement of road embankments made of weathered soft rock-fragments causes many kinds of troubles, e.g. cracks on the surfaces of the pavement. The authors show the convenient methods of tests to define the slaking-rate and the fracturing-rate of these materials. And introduce a classification chart to evaluate the settlement characteristic with these two rates. To reduce the settlement of embankment the degree of compaction must be satisfied the lower air void ratio(less than 15%).

(H-4)

(9) Geotechnical Investigation of Completely Weathered Granite and Ground Behavior due to Tunnel Excavation by the NATM

Isoura, K., Sasaki, Y., Seki, J., Nakamura, T. and Kantoh, K.

Tsuchi-to-Kiso, JSSMFE, Vol. 28, No. 7, pp. 53-59, 1980,

The soil condition of No. 2 Hiraishi Tunnel is completely weathered granite, of which cohesion is very small, but in which minerals are scarecely decomposed. We have applied the NATM to this tunnel under the bad condition of slight overburden (0~14m height) and soft ground. Ground behavior around the tunnel was measured during the tunnel excavation and its result showed the success of NATM.

(H-5)

(10) Foundation of Suspension Bridge on Weathered Granite

Yamagata, M.

Tsuchi-to-Kiso, JSSMFE, Vol. 28, No. 7, 1980,

The design of a substructure consists of determining the type, design condition, and stability analysis. The paper presents the deformation analysis performed for the foundation of Bisan-seto Bridge and the bearing capacity of a foundation on granite in D_M class. The deformation of 7A anchorage was computed using the finite element method which employed the solution technique established with the simulation for the result of creep plate loading test.

The bearing capacity of a foundation was calculated using the shearing strength determined introducing the ultimate bearing capacity obtained with the plate loading test into a bearing capacity equation.

(H-1)

(11) Geotechnical Problems on Dam Construction in the Welded Tuff Region

Momikura, Y.

Tsuchi-to-Kiso, JSSMFE, Vol. 28, No. 7, pp. 75-80, 1980,

Welded and non welded ash flow deposits are recognized at the foot of the huge caldra volcano in the Island arc. The physical and mechanical properties of the deposits are remarkably varied by degree of welding.

In this paper writer points out the neccesity of investigating and analyzing the problems on the dam construction in the ash flow tuff region, which are the geological circumstances, the number of frow cycle, the degree of welding, the unit of flow and cooling, the structure of joint system, the eutaxitic texture, and the amount of essentials and accidentals.

(H-4)

(12) Foundation of Dam of Tertiary Tuff

Nishida, T., Kanazawa, K. and Hoshion, N.

Tsuchi-to-Kiso, JSSMFE, Vol. 28, No. 7, pp. 81-87, 1980,

The foundation of 102m high Ouchi rockfill dam consists of Neogene Tertiary tuff. A low angle fault exists at the base part of foundation and influences as a whole the left bankside abutment, resulting in the fracturing and deterioration of bedrocks. Measurements in-situ revealed relatively low density and high deformability of bedrocks of left bank side abutment. Grouting tests on the left bank abutment assured the possibility of amelioration of its watertightness through grout injection. The dam is equipped with grouting galleries which are specially designed so as to make the future re-grouting of the foundation possible.

(H-4)

(13) The Design of the Underground Power Station and the Measurement of Behavior of Bedrock by Large Cavern Openning

Noguchi, T., Miyake, K. and Nishiwaki, Y.

Tsuchi-to-Kiso, JSSMFE, Vol. 29, No. 1, pp. 29-36, 1981,

A large pumped-storage project, of which name is Tanbara, with an underground power station is under construction at the upper stream of Tone river by Tokyo Electric Power. Co. Inc. This station consists of a machine hall, of which size is 26.6 m wide, 49.4 m high and 116.3 m long, and of a transformer hall of which size is 17.5 m wide, 16.5 m high and 118.0 m long.

This paper shows the outline of the design of the underground power station and methods and results of the measurement of the behavior of bed rock by the large cavern opening.

(H-5)

(14) The Movement of Usage of Underground Space in the World

Shimada, J.

Tsuchi-to-Kiso, JSSMFE, Vol. 29, No. 1, pp. 51-56, 1981,

As the author attended the international sub-surface symposium named "Rockstore '80" held in Stockholm, Sweden, in June 1980, he gives a brief report concerning about the worldwide tendency of the use of underground space based on the papers presented to this symposium. He also introduce some examples of the use of underground space which will be applicable in our country.

(H-5)

(15) The Earthquake Resistant Design of In-Ground Tank

Takegawa, K., Iguro, M., Nakazawa, A. and Ikegami, M.

Tsuchi-to-Kiso, JSSMFE, Vol. 29, No. 9, pp. 53-57, 1981,

This paper presents some studies carried out in order to establish the method of the earthquake resistant design of the inground tank composed of R-C shell and R-C bottom slab. The deformation and stress of the shell are calculated from static linear-elastic finite element analysis by applying prescribed values of displacements on the boundary of which stiffness are modeled by elastic spring. This analysis requires evaluation of the relative displacements between the shell and the ground during earthquake as well as the ground stiffness. In this paper the method to calculate the relative displacements and the ground stiffness is described.

(H-1)

(16) Improvement of Matsumine Mine by Development of the Upper Black Ore Unit

Kotake, Y.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No. 1110, pp. 515-522, 1980,

Matsumine mine being operated by Dowa Mining Co., Ltd. is located in the northern part of Akita prefecture, Japan. The ore deposits in the mine consist of three units (that is, upper, middle and lower units) lying conformably on gentle slope of host rocks and clay zones are intercalated between them. The upper unit is only composed of high grade black ore, but it was difficult to mine it because of its thin thickness and heavy rock pressure from surrounding walls.

High leap of Yen in 1977 following oil shock in 1973 gave rise to deep depreciation of metal price, and the mine fell down into the unprecedented crisis. To survive this crisis, since 1975 the measures were performed as follows;

1) Exploration for the upper black ore unit by up-wards drilling in underground.
2) Conversion of developing system from lateral to vertical and adoption of concrete lining.
3) Development of shield raise machine.
4) Decrease of mining production (50,000t/m to 42,500t/m) and increase of ratio of high grade black ore.

Consequently after 3.5 years, much improvement in revenue and expenditure balance (revenue up 19%, cost down 11%) was realized and the increase of black ore reserve (38% up) was also attained.

(H-0)

(17) On the Development of Safety and Production Technique to Cope with Complicated Mining Conditions in the Akabira Coal Mine

Nakajima, S.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 97, No. 1121, pp. 513-519, 1981,

Each colliery under different geological conditions has accumulated the original know-hows in mining methods, safety measures, etc.

These know-hows have been developed through continuous study and various experiences for a long time.

In the Akabira colliery, under inferior mining conditions due to steeply inclined strata and existence of many faults and folds, we have struggled against spontaneous combustion and gas outburst since opening the mine.

Several noteworthy know-hows mentioned below have been developed in our colliery and their details and developing process are described in this report:

(1) Countermeasure to gas outburst by the execution of release boring with a diameter of 200 mm to 250 mm;
(2) Drilling technique for large diameter holes (750 mm ~ 1,500 mm), so-called "The large diameter ring shaped boring";
(3) Centralized monitoring system with the tube bundle for the early detection of spontaneous combustion;
(4) Fly ash slurry transportation and filling system from the operation plant installed on surface;
(5) Mechanized longwall mining system for steeply inclined coal seam; and
(6) Operation of fluidized-bed combustion boiler.

(H-0)

K. [Construction Methods and Equipment]

(1) Construction of the Dai-Shimizu Tunnel

Nakai, Y.

Journal of the Japan Society of Civil Engineers, Vol. 64, No. 6, pp. 15-22, 1979,

This is to report an outline of the construction of the Dai-Shimizu Tunnel, which is a main portion of the new Joh-etsu trunk line, focussing the technical aspects such as full-face cutting and rock burst prevention.

(K-5, K-11)

(2) Application of Hydraulic Blasting to NATM
Hashimoto, H. and Takagi, K.
Journal of the Japan Society of Civil Engineers, Vol. 64, No. 10, pp. 57-60, 1979,

The aqua-blasting, i.e., directional hydraulic blasting method, was applied successfully in tunnel construction with the new Austrian tunneling method. Its principle, mechanism and characteristics are here reported. Merits in cost and safety are also described in comparison with usual blasting methods.

(K-4, K-11)

(3) Improvement of Poor-Subsoil in a Peat Bog
Kohno, F., Mochinaga, R., Sasaki, H. and Kamada, H.
Journal of the Japan Society of Civil Engineers, Vol. 66, No. 4, pp. 28-34, 1981,

Construction works in a peat bog still encounter several defects. This paper reviews the estimation of the efficiency of improvement techniques and their applicability.

(K-1)

(4) Challenge for Inclined Tunnel by the Tunnel Boring Machine (TBM), - Execution Work at the Shimogo Power Station -
Nishida, T., Matsumura, Y. and Miyanaga, Y.
Journal of the Japan Society of Civil Engineers, Vol. 66, No. 10, pp. 16-24, 1981,

It is very few cases in this country that the execution work of tunnels using TBM was successful; however, this technique will be applied more and more from the view point of safety and economy only if a suitable TBM is developed. The first execution work to the inclined tunnel in Japan was carried out at the Shimogo Power Station and completed successfully in December 1980. This article reports the detail of the above execution work.

(K-4)

(5) Dai San Shirasaka Tunnel Excavated by the T. B. M.
Endo, K. and Takahashi, A.
Proceedings of the 12th Symposium on Rock Mechanics, JSCE, pp. 81-85, 1979,

1. Qutline of Tunnel project

No.3 Shirasaka Tunnel is JNR's double track tunnel having 4260m in length.
We have excavated this tunnel from Jan in 1977 by using Tunnel Boring Machine(T.B.M.) which had been used at bottom heading section in several Shinkansen tunnels.
Excavating length by the T.B.M.is 2945m. We have already finished the excavation at Oct. in 1978.

2. T.B.M.

This machine is called RT-45A. Structures and thrusting mechanism are as follows; This machine have 4.5m dia cutter head and cutter head equip in its front side 33 disk roller cutter. Cutter head can rotate 3 or 6 r.p.m, therefore 4.5m dia Full face excavating methed is possible.
Cutter head is thrusted to the tunnel face by the four oil jacks and then ground rocks are crushed. Rock mucks are trasported by the backet and belt conveyor. Reaction of the trusting force is taken by the friction between the Gripper and side wall of tunnel. Driving of this machine is done by one-man control system.

3. Geological conditions

In these district mud stone of Miocene-in-tertiary is appeared. This mud stone showed quite complexed folding structures and hardly crushed. We classified rock quality of this mud stone to the six steps from D-2 to D-7. Characters and exvavating ratio by T.B.M.are shown as follows.

(D-2 quite few fissures 5% D-3 few fissures 25%) Good.

(D-4 many fissures 39% D-5 quite many fissures 17%) Mean.

(D-6 crushed 12% D-7 extremely crushed 2%) Bad.

4. Thrust and Driving speed

When we make more roughly classified divisions so as Good(D-2,3),Mean (D-4,5) and Bad(D-6,7). Relatious between Thrusting force and pure driving speed are as follows, the worse the ground conditions the less the thrusting force become possible, And is these cases, in spite of incresing of the thrusting force, pure driving speed do not increse. Of cuvrse the excavation do not agree with the execution. That is quite different problems. In the case of Bad coditios, collapse of tunnel top is so hard that we always need pre-supporting. And on the contrany in the case of Good corditions post-supporting is possible, so that Total cycle show quite transverse feature.

(K-4)

(6) Study on Acoustic Emission Activity in I-Steel for Mine Arch Support

Takeuchi, M., Ebina, M. and Watanabe, Y.

Journal of the Mining and Metallurgical Institute of Japan, Vol. 96, No 1113, pp. 821-826, 1980,

Experiments were made to estimate the loads acting on the steel arch support by means of the acoustic emission (AE) technique. By the bending test of the I-steel for arch support, the following results were obtained:

1) The impulsive AE signals of the I-steel began to generate from the level of half of its yielding stress and the AE activity became at a high degree during the process of its yielding. The AE activity of the I-steel formed into an arch at an ordinary temperature was very low. But the laggings on the steel arch displayed the high AE activity under a low load by the friction between laggings and steel or their collapse.
2) In the bending test, it was able to estimate the stress history of I-steel by Kaiser's effect and to locate the sources of acoustic emissions. But it was difficult to estimate the stress history of the I-steel used in mine arch supports, because its AE activity was degenerated due to the bending in the formation of an arch and the noises of the dispersal of rusts from the surface of the specimen were generated.
3) The yielding stress of the I-steel formed into an arch at an ordinary temperature decreased to nearly half of that of the original straight I-steel due to Bauschinger's effect.
4) By normalization the formed I-steel recovered nearly 90% of the original yielding stress and the AE activity slightly.

It will be able to estimate the direction of the load acting on the steel arch by the source location of AE generated between laggings and steel arch. And the I-steel formed into an arch at an ordinary temperature should be normalized.

(K-11)

III. LIST OF LITERATURES

The listed literatures on rock mechanics and related fiels are picked up from twenty six periodicals [1] published in Japan, from the beginning of 1979 to the end of 1981.

The symbols, A–1, A–2, ----which can be seen at the end of each literature are those of classification of I.G.C. The details are described after [2].

The following superscripts marked at the end of each literature mean the kinds of written language:

no-marked	;	in Japanese
*	;	in English
**	;	in French
***	;	in German

NOTE

1)

(1) Journal of the Japan Society of Civil Engineers
(2) Proceedings of the Japan Society of Civil Engineers
(3) Proceedings of Symposium on Rock Mechanics, JSCE
(4) Tsuchi-to Kiso, JSSMFE
(5) Soils and Foundations, JSSMFE
(6) Journal of the Mining and Metallurgical Institute of Japan
(7) Journal of the Society of Material Science, Japan
(8) Electric Power Civil Engineering
(9) Tunnels and Underground
(10) Journal of the Japan Society of Engineering Geology
(11) Journal of the Japan Society of Landslide
(12) Large Dams
(Journal of the Japanese National Committee on Large Dams)
(13) Civil Engineering Journal
(14) Technical Report of Central Research Institute of Electric Power
(15) Report of the Public Works Research Institute
(16) Butsuri-Tankô (Geophysical Exploration)
(17) Zisin
(Journal of the Seismological Society of Japan)
(18) The Journal of the Geological Society of Japan
(19) Mining and Safety
(20) The Dam Digest
(21) Bulletin of the Geological Survey of Japan
(22) Journal of the Japan Geothermal Energy Association
(23) Journal of the Geothermal Research Society of Japan
(24) Journal of the Japanese Society of Irrigation, Drainage and Reclamation Engineering
(25) Transaction of Japanese Society of Irrigation, Drainage and Reclamation Engineering
(26) The Railway Technical Research Institute, Japanese National Railways

2) I.G.C. : International Geotechnical Classification System

A General

A-1 Foundation, Soil and Rock Engineering-Scope
A-2 Historical Aspects
A-3 Bibliographies and Literature Classification
A-4 Textbooks, Handbooks and Geotechnical Periodicals
A-5 Nomenclature
A-6 Companies, Institutes, and Laboratories
A-7 Societies and Meetings
A-8 Professional Ethics and Legal Requirements (incl. Codes of Practice)
A-9 Education

B Engineering Geology
〔Including Descriptions and Case Records of Natural Phenomena.〕

B-0 General
B-1 Soil Formation
B-2 Ground Water
B-3 Mass Movements and Subsidence
B-4 Natural Catastrophes (incl. Earthquakes, Floods)
B-5 Permafrost and Frozen Ground
B-6 Submarine Geology
B-7 Structural Geology
B-8 Extraterrestrial Geology
B-9 Geomorphology
B-10 Mineralogy and Petrography

C Site Investigations
〔**Equipment and Techniques of Exploration, Sampling, Field Testing (excluding Engineering Properties), and Preconstruction Field Observations.**〕

C-0 General (incl. Planning of Site Investigations)
C-1 Airphoto Surveys
C-2 Geophysical Surveys
C-3 Probing (Soundings)
C-4 Exploratory Excavations
C-5 Boring Technique and Equipment and Recording of Results
C-6 Sampling, Handling of Samples
C-7 Measurement of Field Conditions (incl. Groundwater, In Situ Stress)
C-8 Field Testing (excl. Tests for Engineering Properties, see Groups D and F)
C-9 Reports on Site Investigations

D Soil Properties: Laboratory and Field Determinations
〔**Concepts, Theories, Methods of Determination, Equipment and Results.**〕

D-0 General (incl. Laboratory Supplies)
D-1 Classification and Identification
D-2 Physico-chemical Properties (incl. Corrosion, Thixotropy)
D-3 Composition, Structure and Density (incl. Porosity)
D-4 Permeability and Capillarity
D-5 Compressibility (incl. Consolidation and Swelling)
D-6 Shear-Deformation and Strength Properties (incl. Pore-water Pressure)
D-7 Dynamic Properties
D-8 Thermal Properties (incl. Freezing)
D-9 Compactibility
D-10 Properties of Soil Additive Mixtures

E Analysis of Soil-Engineering Problems
〔**Theoretical, Empirical and Practical Methods of Analysis.**〕

E-0 General
E-1 In Situ Stresses caused by Gravity and Applied Loads and Excavations
E-2 Deformation and Settlement Problems (incl. Piles)
E-3 Bearing Capacity of Soils
E-4 Bearing Capacity of Piles
E-5 Earth Pressure Problems (incl. Silos)
E-6 Stability of Slopes, Cuts and Excavations
E-7 Seepage and other Hydraulic Problems (incl. Erosion)
E-8 Dynamic Problems
E-9 Frost Action and Heat Transfer Problems
E-10 Behaviour of Base Courses and Pavements
E-11 Soil-vehicle Interaction (Trafficability)

F Rock Properties: Laboratory and Field Determinations
〔**Concepts, Theories, Methods of Determination, Equipment and Results.**〕

F-0 General (incl. Laboratory Supplies)
F-1 Classification and Identification
F-2 Physicochemical Properties (incl. Weathering Resistance)
F-3 Composition, Structure and Density (incl. Porosity)
F-4 Permeability and Capillarity
F-5 Compressibility and Swelling
F-6 Shear-Deformation and Strength Properties
F-7 Dynamic Properties
F-8 Special Properties of Rock (incl. Thermal, Electric and Magnetic Properties)

G Analysis of Rock-Engineering Problems
〔**Theoretical, Empirical and Practical Methods of Analysis.**〕

G-0 General
G-1 In Situ Stresses caused by Gravity, Tectonics, Applied Loads and Excavations
G-2 Deformation Problems
G-3 Bearing Capacity of Rock
G-4 Stability of Slopes, Excavations and Openings
G-5 Seepage Problems (incl. Drainage)
G-6 Dynamic Problems
G-7 Frost Action and Heat Transfer Problems.

H Design, Construction and Behaviour of Engineering Works
〔**Descriptions; Case Histories; Syntheses of Investigations, Design, Construction (incl. Equipment and Materials) and Behaviour.**〕

H-0 General (incl. General Contracts and Specification)
H-1 Foundations of Structures (Buildings, Bridges, Tanks, etc.)
H-2 Retaining Structures and Cutoff Walls
H-3 Unsupported Excavations
H-4 Earthworks, Embankments, Fills and Dams (for Compaction see K-5)
H-5 Underground Structures (incl. Tunnels, Conduits and Shafts)
H-6 Base Courses and Pavements of Roads, Railroads and Airfields
H-7 Harbours, Canals and Coastal Protective Works

K Construction Methods and Equipment
〔Including Improvement of Soil and Rock Conditions.〕

- K-0 General
- K-1 Dewatering and Drainage
- K-2 Injection Processes (incl. Grouting)
- K-3 Preloading and Soil Replacement by Blasting
- K-4 Soil and Rock Excavation, Processing and Transportation
- K-5 Compaction
- K-6 Soil Stabilization (incl. Mechanical, Chemical, Thermal and Electrical Methods)
- K-7 Piles and Pile Driving
- K-8 Caissons and Deep Piers
- K-9 Underpinning
- K-10 Slurry-assisted Construction of Foundations and Cutoff Walls
- K-11 Anchorages, Tied-back Walls, Reinforcement, Linings and other Supports of Soil and Rock
- K-12 Deep-water Construction Methods and Equipment (incl. Dredging, Barge Dumping, etc.)

S Snow and Ice Mechanics and Engineering

- S-1 Snow and Ice Cover
- S-2 Properties of Snow and Ice
- S-3 Snow and Ice Engineering

A. General

(1) Journal of the Japan Society of Civil Engineers

1. Iida, R., Present Situation of Rock Mechanics, Vol. 66, No. 2, pp. 2-6, 1981, (A-7).

(4) Tsuchi-to-Kiso, JSSMFE

1. Mizukoshi, T., History and Perspective of Underground Condition, Vol 29, No. 1, pp. 5-10, 1981, (A-2).

(11) Journal of the Japan Society of Landslide

1. Takeuchi, A., On the Historical Review of Landslide Disasters and it's Preventive Works, Vol. 16, No. 3, pp. 21-30, 1980, (A-2).
2. Takeuchi, A., A Movement History of the Chohja Landslide Area, Vol. 16, No. 4, pp. 16-24, 1980, (A-2).

(14) Technical Report of Central Research Institute of Electric Power Industry

1. Ishida, T. & Y. Kitahara, The State of Arts from Bibliographies on the Toppling Failure of Slopes, No. 380035, pp. 1-36, 1980, (A-3).
2. Yoshioka, N., Y. Satake, Y. Sawada & H. Yajima, Compiling of Data Bank concerning Map of Japan, Active Faults on Literatures and Earthquakes, No. 380054, pp. 1-21, 1980, (A-3).
3. Okamoto, T., A State-of-the-Art Report on Long-Term Stability of an Excavated Slope Mainly in Over-Consolidated Clays, No. 380059, pp. 1-42, 1980, (A-3).

B. Engineering Geology [Including Descriptions and Case Records of Natural Phenomena]

(1) Journal of the Japan Society of Civil Engineers

1. Yokoyama, A. & T. Tottori, Characteristics of Construction Work of the Daibe Tunnel, Vol. 65, No. 2, pp. 29-40, 1980, (B-3).
2. Yamazaki, T., Expectation to Civil Engineers, Practical Use of Civil Engineering Geology, Vol. 65, No. 7, p. 21, 1980, (B-0).
3. Imaizumi, S. & K. Ueshita, Investigation into Ground Condition by Use of the Satellite Images, Vol. 66, No. 10, pp. 9-15, 1981, (B-9).

(4) Tsuchi-to-Kiso, JSSMFE

1. Yamamoto, S., On Utilization of the Underground Space -with special reference to its feasibility-, Vol. 29, No. 1, pp. 11-14, 1981, (B-2).
2. Kurokawa, M., Groundwater Dam in Miyake-jima of the Ryukyus, Vol. 29, No. 1, pp. 37-42, 1981, (B-2).

(6) Journal of the Mining and Metallurgical Institute of Japan

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D. Soil Properties: Laboratory and Field Determinations
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